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ACID RAIN, 1983

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BEFORE THE
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ENVIRONMENT AND PUBLIC WORKS
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NINETY-EIGHTH CONGRESS
FIRST SESSION

AUGUST 25, 1983—ROSEVILLE, MINN.
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ACID RAIN, 1983

THURSDAY, AUGUST 25, 1983

U.S. Senate,
Committee on Environment and Public Works,
Roseville, Minn.

The committee met at 9 a.m. in the Minnesota Pollution Control Agency, Hon. Dave Durenberger presiding.

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator Durenberger. Good morning. I want to thank everyone for being here. This mornings schedule is rather ambitious and the witnesses are talented, and the time we spend here this morning will be best spent with the witnesses who have been kind enough and concerned enough to fly in from places like Albuquerque and Montana and Washington, and Toronto, Ontario, Canada.

I want to take just a minute to explain why a U.S. Senate committee has chosen to hold a hearing on acid rain in Minnesota rather than in one of the 21 States that somebody in this administration has decided is the only place we have acid rain problems in this country. If you have asked yourself that question, I think you may already have provided the answer. The fact is that acid rain is a potential and real problem in the Upper Midwest and in our State, particularly a problem in the Boundary Waters area almost as much as it is a problem in New England and in Canada. However, most attention focuses on the Ohio to New England access; and so, if I have to pick out one serious important purpose for this hearing in this State at this time, it is that we in the Upper Midwest have a very substantial stake in the acid rain debate.

It is clear that at least some parts of our environment are at stake; what is less clear so far is that parts of our economy in this part of the country and in this part of the world are also very clearly at stake. What you will observe, those of you who are here as observers during the course of this hearing, is that one of the things we are going to accomplish is an update on the acid rain problems since the last time this committee or any of the subcommittees held a public hearing on that subject. You will also hear some testimony on the basis of rather substantial and substantive scientific analysis of the problem of acid rain for the three principla Upper Midwest States which have, within their geographic boundaries, 50 percent of this country's fresh water, and you will also hear a discussion of some of the acid rain control options.

Updating what this committee has usually heard in terms of options, we are now at the point where we are moving beyond the so-called regulatory options into what some people call the tax and spend option. I know that today there will be some discussion about alternative tax and spend options to control the emission of acid rain.

I guess you already know that I am a proponent of the tax and spend option. I am a proponent of the so-called marketplace in the environment, environmental control, the same way I am a proponent of the marketplace in controlling the cost of health care.

I come from a State that is a clean State. It is a clean State because the people of this State over a long period of time have paid to keep it that way. We burn clean fuels to the best we can; and where that's not possible, we clean stack it. There are, however, acid rain control proposals which would finance an acid rain control program by taxing energy everywhere in the United States. Taxes would apply not only in the dirty States in the eastern Midwest but the clean States like Minnesota as well. Thus, those of us who live here or work here would be placed in the position of paying twice: First, to clean up our own pollution; and second, to clean up somebody else's pollution they were too lazy to clean up in the first place.

Acid rain is a national problem. It should require a national solution, and that may well lead us to a national tax if we adopt a tax and spend control policy. But one purpose of this hearing is to explore whether or not there might be a better way to raise money than by taxing energy. I am naturally inclined toward taxing pollution rather than taxing energy. It seems to me that by doing this, we could not only collect money to solve the acid rain problem directly, but we would also provide a tremendous incentive for the pollution that causes acid rain to be reduced.

I want to make one other point today. We focus a lot on acid rain and we have people sitting on lakes and on mountains during their vacations looking up every time it rains to see if they could see acid falling on them, and so sometimes we are perhaps guilty for focusing too much attention on acid rain and not enough on what is probably the worst pollutant in this country and many countries, and that is sulfur. It is a dangerous pollutant because you can't see it.

I always think about the old days of driving down the interstate freeway when one of our famous paper companies here in St. Paul was emitting steam, and everybody thought they were going to die of some gas. Well, if there is a visibility to pollution you can get everybody up in arms about it. The invisible pollutants are something very different. And someone observed to me if environmentalists had their way and God said, "What would you like to change?," a lot of them would say, "Put some color into sulfur so we can trace it." Because we know that as a colorless gas, it comes down a very fine particle of sulphate that is breathed deep into people's lungs and it affects mostly the very young and the very old, and nobody knows it's happening to them. When it takes the form of acid rain, it does direct damage to buildings, it does direct damage to trees, to crops, to a variety of things; and then it does indirect damage that we can't see happening unless we go over to Europe and wonder why green branches are falling off trees for no apparent reason.

So it seems to me that by looking at a tax and spend control policy, we are constitutionally going to lead ourselves to a national control policy since we can't just confine taxes to certain industries or certain States and have them be constitutional. We may end up, in some fashion, encouraging the reduction across this country and maybe, if we have the right handle on the policy across this world, on the emission of sulfur.

So that is an attempt at a brief opening statement to describe what it is that you may hear about today. We have an impressive list of witnesses, and we will get to them right now. I am not the expert here today; all of the witnesses are, particularly with regard to the last subject I have covered which is control policies.

We are very pleased to have with us Dr. Allen Kneese who has been toiling in this vineyard for something like 10 or 15 years. So with that, we will call our first witness.

STATEMENT OF DR. ALLEN KNEESE, SENIOR FELLOW, RESOURCES FOR THE FUTURE

Dr. KNEESE. My written statement starts out by saying, Senator Durenberger and other members of the Environmental and Public Works Committee, but I guess that isn't completely applicable but I do appreciate the opportunity to appear before you today.

As you indicated my name is Allen Kneese. I am an economist and senior fellow at Resources for the Future in Washington, D.C., but in this testimony I present only my personal views. I am not a specialist on acid rain, but during most of my professional life I have been interested in environmental policy and have been involved in much research about it. This is the perspective I bring to these hearings. A copy of my short vitae is attached to the written testimony for the committee's convenience.

As an additional matter of perspective, I feel that because our economy has performed so poorly recently, it is imperative that economic efficiency and cost-effectiveness move up in the scale of priorities in the crafting and conduct of public policy.

In my view, the acid rain issue presents a splendid opportunity to be creative in developing policy on this important issue. The situation giving rise to the problem appears to be an almost ideal one for the application of emissions fees as one element of environmental policy. The policies presently under consideration by the Congress all emphasize an aggregate reduction in total emissions of sulfur dioxide and nitrogen dioxide from a number of large point sources. These sources have greatly differing costs of control per ton of emissions reduction. Levying an appropriate per pound or per ton fee will, in the interest of minimizing costs of producing electricity, induce those sources who can reduce sulfur dioxide or nitrogen dioxide inexpensively to control much and those sources who find pollution control very expensive to control least. A large body of research in environmental economics has shown that under these circumstances the decentralized incentive effect of a fee can come quite close to achieving the level of discharge reduction actually attained at the least resource cost possible. This cost is much lower than that of a policy requiring uniform cutbacks of emissions from each source, not to mention a policy that requires each source or a group of sources to apply the same technology.

Under the emissions fee approach, not only will each source respond with the emissions level that is best for it, but it will use the combination of technological and economic responses that will yield the lowest cost for the level of reduction it does achieve. Costs for alternative emissions control technologies as different sources vary for a number of reasons including the age and layout of the plant, availability of space, and relative availability of low-sulfur fuel to the plant. Quantitative and realistic computer modeling studies in diverse regions of the country have unfailingly supported the cost-minimizing properties of an emissions fee where the objective is to obtain an aggregate level of discharge reduction in a region. Such studies exist, for example, for the Delaware Estuary area, the St. Louis metropolitan area, and the Four Corners region of the Southwestern United States. It is not unusual to find cost savings of 50 percent or greater where economic incentives like emissions fees are used in lieu of inflexible regulatory requirements.

Are there any potential problems with such emissions fees? There may be, and careful consideration of them is merited.

First, revenues from an emissions fee could be used for various purposes. If they are used to subsidize emissions reduction, care must be exercised that subsidies are granted in such a way that they do not undo the desireable efficiency properties of the fee system. This would happen, for example, if the subsidy were available only for scrubbing equipment. All technological options and other means of emissions reduction must be accorded equal status under the subsidy system. These would include, for example, fuel switching and coal cleaning as well as scrubbing.

Second, we are dealing in this matter with regulated public utilities. There is some uncertainty about how they and the regulatory agencies would respond to a fee system. Much would depend upon how the fee was treated by the regulators. If, for example, expenditures made for emissions control could enter the rate base but the fee could not, then it might provide a particularly great impetus to act. These matters need careful consideration.

Currently under consideration is a major alternative to the emissions fee as a way of subsidizing emissions control for acid rain reduction. This is a generation fee, as already mentioned by the Senator, on an electrical generation from fossil fuel in the United States. In the Sikorski and Waxman bill which is H.R. 3400, this latter approach is combined with a subsidy to the 50 "dirtiest" powerplants in the Eastern United States to help them meet the cost of being forced to install scrubbers even though most such plants would, for cost reasons, prefer to go to low-sulfur coal sources. This approach is, it seems to me, extremely questionable public policy.

The only merit of the generation charge is that it spreads the cost thinly all over the country in the hopes that no one will notice it much. But from both an equity and efficiency standpoint, it is perverse. It rewards those who have the dirtiest plants and penalizes those who have either installed control equipment or are using low-sulfur fuel.

Also, the requirement that the 50 dirtiest powerplants be required to scrub appears to be very undesirable from a cost-effectiveness standpoint. My associate at Resources for the Future, Paul Portney, has made some preliminary calculations about the efficiency penalty associated with scrubbing requirements vis-a-vis a policy that would permit utilities to choose between scrubbing and fuel switching to remove sulfur dioxides. Note that this latter is not the full least-cost result that could be associated with an emissions fee since it still requires that each individual plant cut its emissions by a specified amount. The real least cost solution might be much lower than the alternative used for the comparison that I will report shortly.

Portney stresses that the numbers on which he has had to base his calculations are weak and his estimates should be considered highly preliminary. Nevertheless, their size suggests that careful investigation of cost differences among control strategies is merited. His calculations suggests that the scrubbing policy would cost about $1.6 billion per year more than essentially the same regulatory policy that permits fuel switching as well.

Assuming these numbers are reasonable, why should the American public have to pay $1.6 billion more for a policy approach that insists on scrubbing versus a more cost-effective regulatory alternative, not to mention the even much greater real costs savings that could be associated with an emissions fee. Note that these increased costs yield no environmental benefit at all.

The legitimate concern of those proposing the scrubbing-cum-generation fee approach is that miners presently employed in mining high-sulfur coal might lose their jobs.

I will quote from Portney's article in the August 12 issue of the Washington Post on this point. His references to "least-cost" approach refers to the alternative regulatory strategy, not the emissions fee approach.

Even among those used to the boom-and-bust nature of coal mining, involuntary unemployment can be a bitter pill to swallow. But many of the miners would be reemployed in the same or nearby areas, since low- and high-sulfur coal are often found close together. In Appalachia alone, for instance, many more mining jobs would be created than would be lost. At most, net job losses in the Eastern United States under the least-cost approach and that's the least-cost regulatory approach would amount to about 2,000.

Since H.R. 3400 would—

By his calculation—

cost $1.6 billion more than the least-cost approach—

That's annually—

it would soon be forcing Americans to spend $800,000 a year for each mining job it saved, roughly 30 times what each of these miners could be expected to earn in a year. This sort of foolishness begs for a better solution—and one is at hand. Why not simply use some of the considerable savings possible under the least-cost approach to retrain or help relocate any miners and their families?

That's the end of the quote from Paul Portney's article in the Washington Post.

As an economist, and especially as a citizen, I hope we can use this opportunity to take one step toward introducing more flexibility and efficiency into the system rather than adding to the arthritic rigidities that are making it increasingly difficult for the Nation to function for the benefit of all its people.

This concludes my oral and written statement. If I can be of further help to the committee, I will do my best to be cooperative. Thank you.

Senator **Durenberger**. Thank you very much for your testimony.

You talked about the problem of how you spend the money that's raised by a tax. Do you believe that EPA could write a short list of investments that would maximize emission reductions per dollar that got spent? And by a short list, I am probably talking 100 or 200 investments that would get us to a 10 million-ton reduction. Would that be possible for EPA to do?

Dr. **Kneese**. Well, I believe, Senator, that if an emissions-fee approach were adopted and if it worked properly in the utility regulatory process, that that in itself would provide a strong incentive for those plants that have opportunities to reduce emissions at low cost to do so; and if a subsidy system were to be put into effect, one way might be to have the large plants that are responsible for most of the problem provide EPA with proposals as to what is possible for them and have EPA evaluate those proposals and attempt to put the funds first in those areas where the most emission reduction is possible at the lowest cost.

Senator **Durenberger**. Related to that, those are the most knowledgeable people which is why, I assume, in your statement you say let's not force people to go to scrubbing when fuel switching or something else might be better. I have also assumed, and I need your reaction and your advice on this, I have also assumed that if we use this marketplace strategy to get to the 10 million tons, that the folks in the marketplace faced with these options of paying the tax or going to something else are going to start making their own investments.

Dr. **Kneese**. Yes, sir.

Senator **Durenberger**. I will pull a figure out of the air and see whether you have any numbers, but presuming that we are talking 10 million tons a year, that maybe you could count on a couple million tons a year right off the top coming from the election by the marketplace to avoid the tax by making their own investment.

Do you have any notion what might happen out there in the marketplace and how much might be produced?

Dr. **Kneese**. I can't say exactly, of course, and it would depend on the level of the fee. But if the fee were set in such a way that it approximated the average cost of reduction across the plants, you could probably expect a larger response than that just from the people.

And I want to reemphasize that the studies that have been made of situations where you want to obtain an aggregate reduction in emissions, not necessarily to attain an ambient standard somewhere but an aggregate reduction in emissions, have shown that the incentive effect that pushes the plants that have the least cost of control to move will produce a result that is very much less costly than, for example, the required scrubbing, or even a regulatory approach that requires uniform cutbacks. And in the studies that have been made, for example, in St. Louis and the Delaware area and the Southwest, that reduction in cost is sometimes more than half which is a very significant amount to the citizens.

Senator **Durenberger.** Elaborate a little bit on that part of your testimony that alerted us to the fact that utilities operate in a regulated environment. Usually that means that if we impose either an emissions tax or any other kind of tax, the utilities just pass that tax along to consumers.

What, in that kind of environment, is the incentive for the management of a regulated utility to go out and make investments that would help them to avoid the tax?

Dr. **Kneese.** Well, there is certainly some built-ins into the incentives of the utility operators themselves; because while they can pass costs forward, it is true that electricity demand has shown to be somewhat elastic and they are interested in keeping up the demand of their customers. So under ordinary circumstances I think it's fairly clear that utilities tend to behave in a cost-minimizing fashion which has to be the case if the tax approach is going to work efficiently.

On the other hand, the present situation may be a little different than it has been historically. The electricity demand has not been growing much. The utilities are having some difficulty in finding capital in the capital markets, and there may be an incentive to pass forward costs rather than make capital investments. And the reason why I felt careful consideration had to be given to the public utility regulatory process itself, and one rather top-of-the-head suggestion I had that might be looked at is that you permit any costs that the utilities incur for reducing discharges to enter the rate base but not to permit the fee to enter the rate base. In that case it might provide a particularly powerful incentive perhaps.

Senator **Durenberger.** Do you know where else in this country we have anything comparable to this kind of a control program; a basic tax and spend program in effect?

Dr. **Kneese.** Interestingly enough some years ago the Navajo tribe enacted a sulfur emissions fee which has never gone into effect; it's tied up in the courts because of reasons having to do with the type of contracts that they made with the energy companies that specified that the tribe should not have the authority to tax the energy companies—which raises another point that I think needs consideration.

There could be two legal basis for such fee: One is the power to tax which raises things like equitable apportion which you mentioned. There could also be the police power in which case it would be the regulatory fee. And I think it would be worth the committee's time to look at the ins and outs of this question. For one thing if it were a regulatory fee, it might not have to involve the tax writing committees of the Congress which perhaps would be beneficial since their purpose is really revenue raising rather than dealing with those kinds of allocation problems.

Now, there are a number of effluent fee systems in operation on waste water in other parts of the world, not here. A new law has just gone into effect in West Germany which levies fees on effluents discharged to all the water sources of the Federal Republic; and such laws have existed for sometime in France and in some of the east European countries, Czechoslovakia and Hungary, for example. So there is precedent.

In this country we have tended to favor the demand and control regulatory approach to problems of this kind, and we have relatively little experience but there is experience abroad.

Senator **Durenberger**. What about the super fund? How would you compare this approach with the Superfund approach?

Dr. **Kneese**. Well, I think that the Superfund might be more comparable with H.R. 3400 in that it levies the fee not on the thing that's causing the problem.

Senator **Durenberger**. Right.

I thank you very much for your help; and if I may, as long as we are on the record, pledge you to assist us as we expand the scope and look at the alternatives and try to come to grips, in the coming weeks, with a solution to this problem. Given your background in this area you can be very helpful to the committee, and I trust helpful to both sides of the Congress in coming to an answer. So thank you very much.

Dr. **Kneese**. Thank you. I am pleased to have been able to help a little.

Senator **Durenberger**. Our next witnesses will be a panel of four: Mr. Carroll Besadny who is secretary of the Wisconsin Department of Natural Resources, Bureau of Air Management; Ms. Sandra Gardebring, the executive director of the Minnesota Pollution Control Agency; Mr. Walter Giles who is from the Ministry of the Environment, Toronto, Ontario, Canada; and Mr. Robert Miller, director of air quality, Michigan Department of Natural Resources.

If it's all right with all of you, we will proceed to take your testimony in the order that you were introduced, unless between you you have agreed on some other order. That would mean that our friend from Wisconsin, Mr. Besadny, would go first.

STATEMENT OF CARROLL D. BESADNY, SECRETARY, WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Mr. **Besadny**. That's correct, Senator. We did not rehearse ahead of time and I guess I am first on the list.

My name is Carroll Besadny; I am secretary of the Wisconsin Department of Natural Resources with our headquarters in Madison. Actually we are a resource management agency, environmental protection agency, and also an enforcement agency as well.

To digress for a moment from my prepared remarks, Senator, you talked about the color of SO_2. About a month ago I received a letter from a concerned citizen in northern Wisconsin who sent me probably for the first time a little packet of acid rain. It was a little plastic bag with a bunch of yellow material in it. And I took one look at it and while I am not a technician, I assumed there was something wrong and I had it analyzed and one of our folks quickly identified it as red pine pollen. The gentleman was very concerned because he said this horrible yellow stuff came down one night, covered his cabin, covered his picnic table. So he scraped the acid rain off the walls and wanted me to do something about it immediately. So I think somebody has seen something that looked yellow and assumed it was acid rain.

This is the third time in 2 years that our department has expressed concern about acid rain to the U.S. Senate Committee on Environment and Public Works. We have done so because of the serious threat acid rain poses to Wisconsin's valuable natural resources, especially those of our Northwoods region.

Fishing and forestry are particularly important to our Northwoods economy. More than 80 percent of the State's nearly 15,000 lakes are found in 23 northern Wisconsin counties. Statewide anglers spend about $480,000,000 a year pursuing their sport and they purchase 1.5 million fishing licenses. We also sell more fishing licenses to nonresidents than any other state in the country. Tourism in Wisconsin is a $6 billion business.

Income and employment in our northern communities also depend heavily on the region's extensive forests which are used to produce lumber, paper, and wood products. In 1980 forest-based industries in Wisconsin provided about 69,000 jobs with annual wages totaling more than $1.3 billion.

The intense use of our north's waters for recreation and the north's importance as a prime timber-producer are two valuable assets Wisconsin has worked hard to protect and manage. This year, for instance, about 95 percent of the State's industries and nearly 90 percent of our communities met the national goal of fishable and swimmable water mandated by the Federal Clean Water Act—a water quality improvement effort few States can match. This clean-up was accomplished with no loss in jobs or economic prosperity despite the massive amount of public and private money that was spent.

Wisconsin, however, also happens to be located in the middle of the economically depressed Snowbelt. The northern parts of Wisconsin, Michigan and Minnesota have historically lagged behind the rest of the country in economic growth and stability, so much so that special development programs were authorized and funded by Washington in the past. It is ironic now that the future of the two remaining significant economic resources in the region—tourism and forestry—is threatened by pollution whose source is largely external to the region. So it is not only environmental policy we are addressing when we discuss acid rain pollution, it is economic policy as well.

Evidence of our concern about acid rain is seen in the $2 million that has been invested in Wisconsin acid rain research in the last 5 years. What we have learned from our research has heightened our concern and convinced us that several specific actions must be carried out at the national and State level to address the acid rain problem.

So far, our research findings include the following:

One. Of Wisconsin nearly 15,000 lakes, 2,000 in the northern third of the State are so poorly buffered that damage from acid rain is likely if the present rate of acid deposition continues.

Two. Since 1979, Wisconsin has recorded rain and snow that are at least 10 times more acidic than normal. This level of precipitation acidity has caused environmental damage elsewhere in North America.

Three. The annual acid loading rate in portions of Wisconsin exceeds the critical level that has caused lake damage elsewhere. Continued deposition at the present rate in our highly sensitive northern lakes threatens fish and other aquatic life.

Four. Although no biological damage has been documented to date in Wisconsin's lakes, a few highly sensitive lakes in northern Wisconsin have shown decreases in pH and alkalinity. Although further analysis is required, one of our working hypotheses is that these lakes may be showing the first signs of acidification in Wisconsin.

Five. Game fish in several acidic lakes in northern Wisconsin contain mercury levels higher than the U.S. Food and Drug Administration's safe limit of 1 part per million. Acidic water dissolves mercury from rocks and sediment and converts it into a form that aquatic organisms readily accumulate in their tissues.

Mercury is toxic to people who eat such fish. I believe we can conclude that if acid rain lowers the pH of other lakes in our northern Wisconsin area, we can expect more widespread mercury contamination in our game fish.

In view of these research findings in Wisconsin and our understanding of the acid rain problem, we believe that specific measures must be taken now to address the problem.

As we stated in Wisconsin DNR's previous testimony before the Senate committee on February 19, 1982, we support current proposals to reduce emissions nationwide as a means of solving the acid rain problem.

I want to emphasize the need for a national approach. The economically vulnerable Midwest should not be forced to bear the bulk of the cleanup costs while other regions reap the bulk of the benefits.

This is particularly important for Wisconsin. The sulfur dioxide contributors here consist of relatively small, old sources. Wisconsin is the 13th largest emitter of sulfur dioxide in the Nation, yet it has only 1 large electrical generating plant among the top 80 in the country.

Thus, any federally required emission reductions in Wisconsin must be spread over a large number of relatively small contributors that are too old and inefficient to clean up unless large amounts of money are spent for plant improvements and retrofitting. We recognize the need to move ahead. However, we will require financial assistance to prevent Wisconsin from bearing an impossible cost burden. A Federal grant fund derived from revenues generated across the Nation is most appropriate for this purpose.

The following elements should be incorporated into any grant program to control acid deposition:

One. The most equitable means of cost sharing would be to fund the capital control requirements of a program through a kilowatt per hour charge, which, at a minimum, should apply to all public utility fossil fuel electric generating plants in the 48 contiguous States.

Two. Adequate funding should be available to insure that lack of money is not used as an excuse for failure to meet the law's requirements. Still, firm and uniform national enforcement may be necessary in some cases and in some States.

Three. The funds should be distributed to the respective States on the basis of the anticipated cost of the clean-up effort. Maximum flexibility should be provided to the States to use these funds so the most cost effective means of meeting sulfur dioxide reduction targets can be obtained.

Four. Incentives to develop new and innovative technology should be built into any Federal regulations which are developed.

Five. Requirements to reevaluate and adjust initial legislation to reflect the results of new research should be incorporated into proposed acid rain legislation.

Six. Increase Federal support for the types of research already discussed is imperative to fill in the gaps in our understanding of acid deposition. Especially important is the need to strengthen our understanding of the source receptor relationships so that control requirements can be focused more specifically on the areas and sources which are causing the most severe problems.

These actions will help insure a sound and positive approach to this national environmental problem.

At the State level, the Wisconsin DNR has endorsed a bill now before the Wisconsin Legislature that would create a cap or ceiling on annual sulfur dioxide emissions discharged in our State. To allow uncontrolled increases in sulfur dioxide emissions can only worsen the existing acid rain problem and may cause damage in sensitive areas that have not been harmed yet. We hope other States will also cap emissions as an interim measure while we develop federally mandated reductions.

In summary, action is needed now at both the State and Federal level. This includes continued research, and immediate halt to increases in emissions and a Federal program that will require emission reductions. A funding program is also needed to insure that unacceptable and unreasonable costs are not imposed on any one State or region of this country.

I extend my appreciation to you, Senator Durenberger, and your colleagues for inviting me to take part in this hearings here in Minnesota. I am particularly pleased that my colleagues from Minnesota, Michigan and Ontario are here because of the multi-State and international scope of the problem—and the complex political, economic and institutional hurdles we collectively face in meeting it.

I am reminded of the statement made in a recent conservation foundation newsletter addressing acid rain. The foundation, in describing the so-called externalities of the issue—identifying and quantifying the costs and benefits to all—said acid rain is a political nightmare to address. That may be true, but I feel that the time has come for responsible parties of all political persuasions and at all levels to take the best scientific advice available, recognize that there will always be some unanswered questions, and take prompt and decisive national action. Only with national and bipartisan congressional action and enlightened leadership from this Nation's executive branch on this issue will States like those represented here today and the Province of Ontario be able to do their share, assured not only of meaningful controls but equitable sharing of costs.

And Senator, if time will permit in the next week or so, I will have my staff who are technically trained in this area provide you with more details on my statement.

Senator **Durenberger**. Thank you very much for being here and for your statement.

Miss Gardebring.

STATEMENT OF SANDRA S. GARDEBRING, EXECUTIVE DIRECTOR, MINNESOTA POLLUTION CONTROL AGENCY

Ms. **Gardebring**. Senator Durenberger, on behalf of the pollution control agency, we thank you for the opportunity to address this issue again. As you are aware we have commented on the acid rain issue generally and on various legislative proposals several times in the last year. You have been personally very responsive as has your staff as well as the staff of the committee, particularly Mr. Moore, so we thank you.

As you know, because of the previous contacts, acid deposition is of great concern to Minnesotans throughout the State. Due to the glacial and geologic history of our State, much of the northern and northeastern part of the State is sensitive to acid deposition.

Our studies here at the pollution control agency and with the assistance of the Minnesota Department of Natural Resources and the EPA Water Quality Lab in Duluth have given us a significant data base, and it shows that the State's natural resources like that of Wisconsin are truly threatened. We have learned, for example, that about 3,500,000 acres of forest soils in Minnesota are sensitive or potentially sensitive to acid deposition. That represents about 19 percent of the forested land in Minnesota.

Although Minnesota is known as the Land of 10,000 Lakes, we really have more than 12,000 lakes larger than 10 acres. Of those, we believe that between 1,500 and 2,500 lakes in Minnesota are sensitive or potentially sensitive to acid deposition. Again, that's a major share of our lakes, about 25 percent of the lakes which are classified as fishing lakes in this State.

In addition to our concerns about lakes and forests, we have now estimated that about 1,200,000 acres of peatlands in Minnesota may also be threatened. Some of these sensitive peatlands represent a unique wilderness of wildlife and vegetation that cannot be found in any other State outside of Alaska.

Altogether, our estimates include that about 15 percent or almost 8,000,000 acres of Minnesota's forests, peatlands, and watersheds are sensitive to acid deposition. And these areas are sensitive to acid deposition. And these areas cover much of the eastern and northeastern part of the State and include the Voyageurs National Park, the Superior National Forest, and the 1 million acres of the Boundary Waters Canoe Area which some people have called the Crown Jewel of Minnesota. These threats to the biosphere of Minnesota translate to real economic threats as well.

Again, as in the State of Wisconsin, agriculture, tourism, and forestry are the three largest industries in Minnesota. Two of these industries, tourism and forestry, are already seriously threatened by acid rain because of the sensitivity of the resources that support them. Agriculture, though not currently threatened, could be affected if rainfall becomes more acidic in the future. On the tourism side the estimates that we have done show that the first signs of lake acidification in the BWCA could result in an annual loss of about $40 million per year and up to 3,000 jobs. And that, of course, represents only a fraction of the total tourism and sport fishing industry in the State.

Our estimates and our studies are already showing that rainfall in Minnesota ranges from well-buffered rain in western and southwestern Minnesota to highly acidic rain and pHs in 4's in extreme northeastern part of the State. Unfortunately, the rain is most acidic in those areas that are most sensitive. And again, like Wisconsin, while we have found no dead lakes yet, we are beginning to see the kinds of changes that suggest difficulties are coming. The acidity of precipitation and the rates of deposition in northeastern Minnesota are already great enough to begin causing those subtle chemical changes. Our computer modeling shows that about 30 percent of the acid deposition in our State is a result of our own emissions and the rest comes in from outside. About 20 percent is from all our friends in Canada, and about 50 percent from the rest of the Nation, including States to the west of us. We think that probably Missouri and western Illinois are the two major sources of acid deposition in our State.

Because we have recognized that our hands are not clean, that is our own emission contributes significantly to acid deposition in our State, emission of sulfur dioxide in Minnesota are already much lower today than 10 years ago. We intend to reduce emission even further through the implementation of the 1982 Minnesota Acid Deposition Control Act which is a statute certainly unique in this country and I think perhaps unique in the world. This act establishes Minnesota as the first State to begin regulating acid deposition, and we have already developed a formal inventory of sensitive resources. We are now in the process of developing a control plan which will be put in place by January 1986, and we hope lead to compliance with an acid deposition control standard by 1990.

Even though that act sets a rigid schedule for reductions by estimating the 1990 compliance date, we have already begun reducing emissions. Northern States Power Co., at our request and voluntarily has agreed to reduce emissions at three of its existing powerplants in order to offset emission growth over the next few years. That is an approximate 12,000 ton per year reduction above and beyond anything required for emission limitations, achieving ambient levels, or any other existing control program.

This action I think demonstrates two things: First, that we can reduce emissions and accommodate future growth of the utility industry; and also that there are utilities among the American utility industry that are responsible and willing to take action now even in the face of some uncertainty about exact data issues.

As far as Federal action is concerned, we have, I think like our sister States, been frustrated by the inability of the Congress and the administration to come to terms with this issue. One example of our response to that has been the Acid Deposition Control Act, and the other is the recent agreement we reached with Ontario to begin working across the international border to deal with this issue. The agreement represents a commitment by the State and the Province to work together on technical issues, to share data, to do some joint computer modeling, and to do as much as we can with our resources in the Province and the State to deal with the issue.

We have, of course, been looking to Washington and to the Congress for a national proposal, and we have been reviewing the various legislative initiatives that have been coming forward over the last several years. We are concerned that any Federal legislation address acid deposition in such a manner that will insure adequate protection for Minnesota's special resources. The steps necessary to control such deposition in Minnesota are similar but at the same time perhaps geographically different than those necessary to control acid deposition in other parts of the country which are already severely impacted, particularly New England. This is because, as I mentioned, the sources that contribute the most to acid deposition in our State may not be the same as those contributing significantly to the New England problems.

The concepts that I'm going to talk about in a minute will strive to address the geography of the situation; and these are basically half a dozen principles that we think should be incorporated in any legislation that the Congress would adopt.

First, we believe an interim freeze or cap on total U.S. emissions of sulfur dioxide from major sources, that is any of those above 100 tons per year, should be initiated to insure that emissions of sulfur dioxide do not increase until a Federal control plan or legislation is enacted.

Second, again to help accommodate future growth, we believe all major new sources should be required to employ the "Best Available Control Technology."

Third, we believe that the focus of the program should be on sulfur dioxide. Current research indicates that sulfur dioxide is the pollutant that is primarily responsible for long-term acidification of lakes and other resources. Because more is understood about its effects as compared to the effects of NO_x, we think the focus should be on sulfur pollutants.

Fourth, we think that the program should be a national program including all States. Acid deposition is not just an eastern U.S. problem. And as I indicated earlier, the control strategies to deal with the problem in Minnesota may be somewhat different than if we focused just on New England.

Fifth, we think to adequately protect sensitive resources in the United States and Canada, we need a reduction in the area of about 50 percent. This represents a reduction of 10 million to 12 million tons per year in the United States.

Sixth, we believe that strengthening language should be added to the existing provisions addressing interstate pollutants in the Clean Air Act to provide for alternative mechanisms should the national legislation to control acid deposition in particular not become a national program.

Finally, we want to comment on the funding mechanism. I have discussed this issue with the Minnesota Department of Energy and Economic Development and the Department of Public Services, as well as the staff of the Public Utility Commission, and really represent a consensus of our views on that subject. Most current Federal legislation that controls air and water pollution revolves around the concept that the polluter should bear the cost of pollution control. Ideally that concept should work for acid deposition as well; and, therefore, we prefer that there be no funding mechanism that spreads the costs nationally.

However, we recognize the necessity of developing legislation that is politically acceptable to the Congress in order to achieve our goal of mitigating acid rain; and, therefore, we understand that a funding mechanism may be necessary if any bill is to move this year in Congress. If some type of funding mechanism is to be included, we prefer one that recognizes the existing degree of pollution control in our State. An emissions based funding source such as a sulfur dioxide emissions tax would meet that requirement. On the other hand, our concern is that the generation tax approach would not adequately take into account SO_2 reductions that have already occurred; and would therefore potentially, at least, work an inequitable burden on Minnesota taxpayers and rate-payers. Until we have the specifics of any proposal before us, we can't know the exact cost to Minnesota; but we do think that either mechanism, that is either the generation tax or the emission tax, is not likely to be a terrible burden on Minnesota taxpayers. And in any case we think it's likely to be offset by the benefits of controlling acid rain.

Senator, we have enjoyed the opportunity to work with you and your staff on this issue. We think that our ability to deal with these questions is going to be enhanced by our cooperative effort with Canada. We stand ready to assist you in any way as you develop your policy approach on this issue, and we look forward to the opportunity to further discussion.

Thank you very much.

Senator **Durenberger.** Thank you very much.

Our third witness is a friend from Toronto, Mr. Giles.

Dr. **Brydges.** Good morning.

First of all let me correct the situation. I am not Walter Giles; those of you who know Walter will recognize that fact right away.

Senator **Durenberger.** Obviously the chairman does not know Mr. Giles.

STATEMENT OF DR. TOM BRYDGES, MINISTRY OF THE ENVIRONMENT, TORONTO, ONTARIO

Dr. **Brydges.** Mr. Giles is enjoying a very well deserved holiday at the present time in Europe and is unavailable this morning so I am here. My name is Tom Brydges.

I will briefly explain, in Ontario we have a six-point program on acid rain. We have an atmospheric component, forestry and soils, aquatics, economic, legal, and information; and my job is the coordinator of that program and trying to keep those six groups going essentially in the same direction. And I call them the Six Food Groups because if nothing else, they are keeping me eating right now. So my role is to keep that and I report to Mr. Giles, and I am very pleased to represent the Province of Ontario this morning on his behalf.

I would like to pick up on a point you made earlier that acid rain is a national problem. I am here because, of course, as you well know, acid rain is an international problem as well. Canada and the United States are living on this continent together, and this problem is being caused by both of our countries, it's affecting both of our countries, and it must be solved by both of our countries. Ontario has taken a number of actions, of course. In the research area we are proud of the fact that we have recently signed working agreements with the States of New York and Minnesota, and these agreements are designed to exchange information so that we can all get a better understanding of the acid rain problem. We accept that many things about the problem are not known. The research is expensive and the research requires data from large numbers of areas, and we are pleased to join forces with those two States—of course with all the others as well, in a formal way with the two States—to help our research become more effective in terms of costs and also to give us a better understanding because that's what's needed to solve the problem.

I have circulated a text which is before the record. What I am proposing to do here is to simply take the three key issues that are raised in this text; and I will briefly describe them in words for you, and perhaps you would have some questions later on in the positions we are taking.

The first key issue that Ontario is concerned about, indeed all of Canada, is that we have huge geographical areas in Ontario, Quebec, Nova Scotia, Newfoundland, some areas of New Brunswick, that are both sensitive to the effects of acid rain, that is they have very low alkalinities in the surface waters, all on Precambrian rock, thin soils, and many of these areas are also receiving elevated acid deposition. We now feel that there are lakes and rivers that have already been damaged. The lakes that are currently being damaged certainly are in the tens of thousands of lakes. In total between Ontario and Quebec there is an alleged 1½ million lakes I believe is the figure. We don't know because we simply can't count them all. So we are, in fact, in Canada dealing with a huge geographical area which is being damaged. We are concerned, this is one of the unique areas environmentally in the world, and most of the species are still there—some of them are being lost—but it's our desire, of course, to prevent further damage. We still feel that in the acid rain situation for Canada, a lot of the actions can still be regarded as prevention of complete destruction if the damage is allowed to continue. So we have these large areas in Canada.

In Ontario the recreational industry for sport, fish, and aquatic-related industry is valued in Ontario at hundreds of millions of dollars per year. Anything that threatens the viability or makes that industry more difficult to manage is, of course, a big economic concern to us. The forestry effects are quite controversial; we are certainly looking very closely at the effects in Germany and the effects in the northeastern part of the United States. In Canada some 1 person in 10 works in the forestry. That industry has threatened the economic consequences for Canada and Ontario are obviously quite large and would outweigh many of the disruptions in the industries that would be effected by a pollution-control program.

So the first point that I want to leave with you is that we are concerned, we have a very real problem, Canada is a very large area, it has very grave environmental consequences and certainly potentially large economic consequences.

The second point that I want to draw is that over the last 2 years we have worked very hard with our counterparts in the United States on the reports under the Memorandum of Intent Activities. It was the memorandum that was signed in 1980 that was to work toward first of all producing reports that described the status of the problem, what was to be done about it, reports on how the problem could be solved, and then leading to negotiations between our countries to, in fact, solve this problem. Of course these negotiations follow the pattern under the Boundary Water Treaties of 1909 where we solved the problem of the trail smelter in the 1930's, the Great Lakes problems; and I think we are very proud of the fact that as two countries, we have worked together and we look forward still to further actions under the Memorandum of Intent Activities.

We supported the work with our research and with our people, and we strongly support conclusions which were reached that a target loading of some 20 kilograms per hectare per year of wet sulfate would be at least the minimum that would be required to protect the environment. We feel that that is a very solid number in spite of criticism, and that we think that we can't go wrong if we aim for that figure. There is perhaps a debate as to whether we should go beyond that figure or not in terms of reductions of deposition. But certainly we feel very strongly in Ontario that that is a good number, it's very well defended scientifically; and as time goes on, we are getting more and more scientific information from things such as the agreements we have with New York and Minnesota and our own research. So we strongly support the Memorandum of Intent number and any programs which would relate to that.

I am going to finish off my comments with, in fact, some discussions about the control programs which are the nub of the problem. I think many people now recognize the problem that something has to be done, the essence of the hearings now are what we are going to do about it and what is the best approach.

I think there is one thing you have to always keep in mind when you hear information and you hear presentations. Historically in the 1960's, the 1970's, and back to the 1950's both in your country and in our country there were a lot of local air quality problems which resulted from local industries. These local problems required local solutions. Those solutions involved a wide range of activities all the way from fuel switching—which is not a new thing, we have been using washed coal in many areas of both countries for years—scrubbers were installed in some cases, emissions reductions were affected by alternative technologies by putting in sulfuric acid production plants and so on. A large number of things were done. We introduced the air pollution index which now requires that industries cut back over the short term if air pollution exceeds local air quality. But that's all history. In both countries we have a very good track record, I think, in improving the local air quality.

Unfortunately, one of the methods we used in both countries was the invention of tall stacks which, of course, moved the problem very nicely from the local area to the long range transport aspect.

In 1981 following on the Federal Ministry's commitment that Canada would achieve greater reductions under the Memorandum of Intent Activities, the Province of Ontario issued two orders on two of our major polluters. Ontario Hydro which is required to affect about 43 percent reduction in its acid gas reductions by 1990, and INCO which is the world symbol of acid rain.

I recently received a set of slides from Sweden. There was this little slide presentation on acid rain. And the slide right in the middle of all this presentation showing an emissions source was none other than INCO in Ontario. It's become the international symbol of all that's wrong with tall stacks and emissions. And INCO was a very severe local problem. And from the 1960's until 1980 they effected something around a 50-percent reduction in their emissions to control local ambient air quality plus building and commissioning the superstack in 1972 which is still, I believe, the world's tallest stack. There has been proposals to actually put about 500 feet of dirt at the bottom of that stack so it would then only measure—and they would no longer have the world's tallest stack. I don't know whether that's a viable solution to the problem or not; I suspect not. But we have been faced with that problem in Ontario for many years. We feel we have dealt with it; we have dealt with it from the local perspective, and now in 1981 we issued another control order which INCO met at the beginning of 1983 where they are now down to 1,950 tons per day, down from about 7,000 tons per day back in the 1960's. It's about a 60 to 70 percent reduction in emissions. This has been achieved by instituting acid gas—of sulfuric acid production and pure-type rejection. INCO could go back up to almost full production and still meet—virtually full production and still meet the control order. It is not just a result of reduction in production. The reduced production is actually putting them below the control orders, but they could actually produce at virtually full capacity and still meet the control order.

The important thing I want to leave you with here is that we couldn't deal with these problems as local ambient air quality problems. They met—both Hydro and INCO met local air quality problems, so we were faced with dealing with the long-range transport problem. What we did, we had the option of issuing a control order; and our lawyers advised us that if we did that, INCO would challenge the order and we would institute the world's longest running acid rain conference in trying to enforce that order. So what Ontario did was use a little tougher approach, we simply passed a law in Ontario which said that for both Ontario Hydro and INCO, they must meet these abatement programs under provincial law with no appeal. They screamed and yelled because they are only 1 or 2 percent of the problem as every industry says, but they are the only ones that we have so we had to deal with them. No matter how big a percentage of the problem, they are our problem; we feel that we have dealt with it.

And I will complete my comments by throwing our full support behind the concept of least cost. Ontario's philosophy has always been, we legislate what must be done; we don't legislate how it is done. We are not into the business of telling companies how to achieve their objectives. We assume that they will do that in the most least cost, technologically advantageous method. And we find our track record in that area has been very good. In a number of areas where industries have, in fact, by giving them the running room and letting the free enterprise system operate, let them do and very often they effect pollution control and gain improved technology and improved production at the same time. We applaud that and support that. We are not in the business of ejecting legislation which will require industries to do something which is not in their best possible economic advantage provided they still meet the environmental objective.

So I leave you with that point that we support the least cost approach, and we are looking forward—and I can only simply say that this is how it has been done in Ontario, and we think we have some lessons that we have learned which we would like to share with you as I am doing this morning and would be glad to share with you further. And we would hope and look forward to resuming the negotiations with the United States which we believe will produce an ordered and effective North American control program which will protect all of the sensitive areas both in your country and in ours.

Thank you for your attention.

Senator DURENBERGER. Thank you Mr. Brydges. I hope Mr. Giles is enjoying his holiday. We enjoyed your testimony here today.

Our last witness on this panel is Robert Miller. Welcome.

STATEMENT OF ROBERT MILLER, DIRECTOR, AIR QUALITY, MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Mr. MILLER. Thank you.

The State of Michigan appreciates this opportunity to present our concerns on the issues of acid deposition. Today I would like to touch on several aspects of the acid rain problem which I think will be of interest to this committee.

We have not in Michigan seen recognizable damage contributed to acid rain. However, that does not mean that we believe there has been or will be no damage. The reason I say this, is that we have a critical lack of data concerning the damage that aquatic and terrestrial ecosystems have suffered in the State and the potential damage that could occur. However, we all know that we have areas susceptible to acid deposition. Based on the geologic history of the upper Great Lakes region, the western end of Michigan's Upper Peninsula is particularly susceptible to damage from acid deposition due to the lack of compounds to neutralize acid input. This is an area of numerous lakes and streams and many of them of low buffering capacity.

The recent study by EPA's Duluth Research Laboratory indicated that of 70 Upper Peninsula lakes studied, nine were acidic. Additionally we have a number of lakes and streams in the western Upper Peninsula of lower alkalinity which, of course, indicates that they are susceptible to acid deposition. Certain types of brook trout have been found to be strongly affected by acid rain. These trout are found in many lakes and streams in Michigan, particularly the Upper Peninsula.

I have heard some people say maybe acid rain isn't all bad because it keeps those trout fishermen out of the way of us water skiers, but it's of great concern to brook trout fishermen.

Since Michigan receives considerable snowfall each year, our potential for sudden damage to aquatic life due to spring runoff of accumulated acidic inputs is increased.

I want to emphasize that due to the amount of agriculture, commercial forestry, sports fishery, and the use of Michigan's water resources that occur in the State, acid deposition impacts could have a substantial effect on our economy. Commercial forestry in Michigan is a $1.2 billion industry; this ranks among the top five States in the Nation in this respect. Use of pine pulpwood and saw logs from Michigan support an important part of northern Michigan's economy. If, as hypothesized, Michigan's pine forests are its most vulnerable, growth reduction would result in considerable loss of forest revenues. Agriculture in Michigan is Michigan's second largest industry representing $2.4 billion annually in income and more than $8 billion including processing. One of the crops found to be most suspectible to air pollution damage is dry edible beans. Our State is first in the Nation in production of these beans.

Over 40 percent of the area within Michigan's political boundaries is fresh water. The State has approximately 11,000 inland lakes of which 2,000 have an area greater than 50 acres. Inland fisheries alone have a total economic impact of $250 million per year in Michigan. The revenues from the fishing industry in Michigan rank highest among all the Great Lakes States and among the top in the Nation.

We know that Michigan is receiving acid deposition. We have been monitoring wet deposition since 1981 and 13 sites along the Great Lakes shoreline; in addition, there are four sites as part of the national atmospheric deposition program network. We have found in Michigan annual values ranging from 3.8 to 4.6. Annual average value for last year was 4.2, and we have had weekly values of acid deposition, that is, individual samples, as low as 3.1. This is on the order of 150 times more acid than normal rainfall.

Limited snowmelt studies in the winter of 1981 showed a sharp drop in pH with first spring runoff with as much as 2.4 pH units in the runoff. An acid fall such as this has been found hazardous to fish especially in spring's early stages of development.

No technical support for any fingerpointing as to which sources are causing Michigan's high deposition levels is available. Due to the huge resources necessary to use long-range transport models, it's more appropriate, we believe, for the EPA and national researchers to perform such an analysis rather than a single State.

I would call your attention to a detailed technical investigation by Dr. George Wolf of the General Motors Research Laboratory in Warren, Mich., which indicates that transports from high SO_2 source areas in the Midwest extend not only to the Northeast but in some instances over the Atlantic Ocean returning over the Southeast and back toward the Midwest; in other words, a singular pattern that covers the entire eastern part of the United States, pollutants coming on shore off the Gulf of New Mexico into New Orleans that were maybe generated in the Midwest. Thus, although prevailing wind directions would indicate transport from areas to the southwest of Michigan, such a broad circulation pattern would lead to transport from other source areas as well.

Michigan's concern for environmental protection has led to the State's adopting some of the most stringent sulfur dioxide regulations in the Midwest requiring statewide control, not just plant-by-plant control. In Michigan we have limits on our large utility plants of one percent sulfur in fuel which is equivalent to 1.6 pounds of sulfur dioxide per million Btu. For smaller plants, usually industrial boilers, our limit is 1.5 percent sulfur which is 2½ pounds of sulfur dioxide per million Btu.

In Michigan we have cut sulfur dioxide emissions by 54 percent in the last 8 years, that's 1974 to 1982, and we have cut them by 36 percent since 1979. This is a reduction from 1.6 million tons in 1974 to 0.7 million tons in 1982, and further sulfur dioxide emission reductions are scheduled to take place in 1985.

Michigan emitted only 22 pounds of sulfur dioxide per megawatt hour of electricity generated in 1980. It was considerably less than other industrialized States including Illinois, Indiana, Ohio, Kentucky, West Virginia, and Pennsylvania. Michigan has a smaller sulfur dioxide tonnage than any other large industrialized State in the

Eastern United States. We have taken the initiative and we have borne the control cost while other States have not done so. For this reason it is very important to Michigan that States that have done a good job in the past in control efforts for sulfur dioxide should not be penalized by acid deposition legislation but should receive credit for these efforts.

While a few States are acting, the problem obviously demands congressional attention. And we in Michigan support nationwide or at least regionwide control of sulfur dioxide now. We can't afford to wait until every bit of research is complete before beginning action.

Now, as to the issue of funding mechanisms, it's easy to say let the polluters pay. But I have come to believe that in my discussions with people from other States that a political reality necessitates sharing the cost. It's a national problem and it can't be blamed on a few States. I believe that a graduated kilowatt hour fee would accomplish spreading the cost and easing the concern about coal mining jobs in the Midwest. I believe that this is what it will take to get meaningful legislation. For some States, and Michigan is one of those, a fee system that sends money out of our State where we have controlled sulfur dioxide to other States that haven't is going to be a bitter pill to swallow. But I think it's come to the time when we have to put our colloquial interests aside and that we have to become statesmen on this issue of acid rain and address it nationally.

Thank you.

Senator DURENBERGER. Thank you very much.

Let me start with a question, and I am informed that we are running out of time. But then I am also reminded that I said at the beginning that you are the experts and I am not. So I will have questions to submit to all of you for more detailed response in writing.

One observation you mentioned, Mr. Miller, the competition between the trout fishermen and the water skiers, and I thought while Miss Gardebring was talking about how much of Minnesota's acidic precipitation is being buffered by the fact that yesterday we were in Moorhead talking about eliminating that buffering by controlling soil erosion so that all those buffering compounds don't come sailing into Minnesota from North Dakota and South Dakota which are really a big help to us here in Minnesota in preventing these effects. So there is something wrong or something right about everything we do in this.

Sandra, you mentioned the Dodd-Durenberger interstate transportation bill and the fact that we need to strengthen that a little bit. Four years ago when I first came to the Senate I cooperated with Dan Moynihan in trying to get first a commitment and then adequate funding and research. And I need each of you, particularly those of you who are dependent on national research efforts to tell me how comfortable you are with our present acid rain research program. Is it producing the kind of information we need; is it not producing the kind of information we need; is it producing a lot or the wrong kind of information; why is it that we are picking up the newspapers in the morning and finding we are going to go off and explore something new? Is this just the source receptor relationship problem, or what is the state of information and how much more do we need before we proceed in the direction of a control policy of some kind or other?

Anybody want to start with that one and give me some observations on where we are?

Ms. **Gardebring.** Let me start very briefly.

I think we are lucky in Minnesota because we have the EPA lab here. We have been able to work very closely with Dr. Glass and his associates in the development of data. I do not think that the issue is a data-gap issue. It seems to me the issue is one of political and it really requires us to move forward. There are certainly some areas where we need additional research, but we need additional research on hazardous waste technology and a host of other things as well as where we have chosen to enact regulatory measures.

I think we can look to the Canadians for some assistance in this regard; Mr. Brydges and his staff have provided us already with additional modeling capabilities, and I think the Canadians on this issue are really far ahead of us. So I think there is sufficient information to act. I think the various science reports and some of the other reports development lately are coming to that concensus even though we all can recognize individual places where more work needs to be done.

Senator **Durenberger.** Who else wants to respond to that question? Mr. Miller?

Mr. **Miller.** I would generally agree with that. We really do need help in the area of analyzing the effects of the acid rain, the damage that's been done, and resources to the Duluth Lab I understand have been cut drastically, and that's the sort of thing that we just can't afford to do now. The study in Michigan was originally intended for 250 lakes and have ended up being 70 lakes. So I would have to say I don't think the research has been adequate and has given us the kind of answers that we would all like to have had.

On the other hand, I don't think we can wait for it to be done to go ahead with the control. We have seen an issue to be dealt with in the Great Lakes and Lake Erie and Detroit where phosphates were involved, and people raise the same issue, well, let's don't require control on phosphates until we have better research. But I think there was as much evidence there as there is here that probably that's what you have got to do to control phosphates and solve the problem of Lake Erie. So we went ahead to do it and results have shown that that's the case.

And I think there is a similar situation; there is a lot of research that has to be done but control has to go ahead rapidly at the same time.

Senator **Durenberger.** What are we going to get out of this if we go ahead with this 15- or 21-State region that I have been reading about? What is the great value of that? Would that add dimension to what we are already doing? You don't have to be familiar with the proposal, just tell me if we are wasting time and effort by concentrating on only 15 or 21 of the States. Maybe I could call on Dr. Brydges to comment on that.

Dr. **Brydges.** I think there is great potential in that area. What you are getting at in principle, the number is not relevant, the point is really to target your first cut control programs. Go for the best bang for the buck, that's what you are going for. Get the best environmental payoff for the least possible cost in the first round.

As long as it is regarded as a first round approach, I think the concept is fine. In other words, if you can get a large control program that would affect let's say 15 States, but it takes a lot of the loading off the sensitive areas, it's a good approach to go. I think that the concept—there is a tendency among industry to sort of look for the free window, where do we situate so that we can continue to pump whatever we like into the atmosphere without any effect. I don't think that window exists. I think that's the trap of any reduced State. I think we have learned from this problem that sooner or later what goes up comes down; and in many cases, I think of because of heavy metals which we haven't touched on much here this morning, there is a lot of things that I believe are going to come out of the atmospheric pollution problem. So as long as you don't fall into the trap or collectively we don't fall into the trap thinking that if we go for a few States that's the end of the problem, I think it's a good first step approach.

Senator **Durenberger**. Would one or more of the three of you react to that?

Mr. **Miller**. I think it's a good first step approach. I think that it's politically one that can probably be taken and that's what's important is getting some consensus of what is a good first step approach to take. And up to now we have all been looking out for our own special interests and there has just been a lot of feuding, and I think we have to settle on something that is politically viable. And I think that that's something that has a good chance of flying, and therefore it's a good place to start.

Mr. **Besadny**. Certainly I think we in the Midwest and other States around us are looking at what has happened in Europe and we have adequate data right now to initiate some controls. I have been a former researcher in our department for years, and I think one of the concerns I have is that when you enter a research project, the bottom line is we need more research. There comes a time, however, when one has capping some of our emissions, to start reducing them, to learn from to fish or cut bait, and I think we are at that point right now to start capping some of our emissions, to start reducing them, to learn from the research that we have to date and with some of the research that's continuing.

In Wisconsin with the $2 million that we have spent in the last 4 years or so, a fair amount of this money was provided by the utilities to help us understand our problem better.

What we thought was somewhat unique at least in the Midwest was to do something that was somewhat unpalletable to the environmentalists, and that was to take a lake that had an average pH and to actually acidify that lake to see how fast one can acidify it under controlled conditions and then try to bring that lake back. Because what do we do in this country and elsewhere when we find that we had lakes that are acidified and creating problems, what's the next solution? We already have lakes that are perhaps in no-return situations and what do we do then? Fortunately a lot of the environmental people in Wisconsin have said that we are the Environmental Protection Agency and why are we going to destroy something. But we felt very strongly that here was a way to learn more about acid deposition. In fact, EPA is ready to finance that study, but I became a little squeemish politically and asked our legislature to endorse that project. At first there was some endorsement and now some legislators are not too sure.

Senator **Durenberger.** Sandra, would you be a little more comfortable with this 15- or 21-State regional approach if the administration had at the same time or in advance of that endorsed some kind of a national control approach, or can this stand on its own and we can continue to debate how to approach the problem on a broader scale?

Ms. **Gardebring.** One always hesitates to be negative when the administration comes forward with a proposal for controlling acid rain, but our concern really is that the sources which potentially impact us may not be the same sources that are likely to be addressed in a regional kind of control program. So I think we need to look very carefully at the details of what's being proposed to make sure that it's broad enough to get at the kind of problems that are causing our own difficulties in this State. We are not the same as New England; we are not the same as New York. We have different upper atmospheric wind patterns to deal with, and I think we have got to look at that very carefully.

So I appreciate the idea of a first step. My experience on these issues is that sometimes we never get to the second step and it's very hard to push on to the next level of controls. So I am, I guess, heartened by the fact that there is some movement to put a control strategy in place; I am worried that it may not be sufficiently broad enough to protect Minnesota's resources.

Senator **Durenberger.** I appreciate the input. I think I have arranged to meet with Bill Ruckelshaus next Monday afternoon; it will be very helpful to know the degree to which there is support or nonsupport for this kind of proposal and that kind of conditions might be placed on it.

On the issue of if we go to the least cost approach and adopt some kind of tax and spending technology, I think I heard you say, Mr. Besadny, that you have a deep concern with the impossible cost burden for Wisconsin, but then Mr. Miller said we have got to stop thinking like that. Obviously some of us are better off than others, and we have got to learn to share the burden. Both of you seem to come around to a tax that picks on only one part of the problem. I am not sure why.

I think you, Mr. Besadny, qualified by saying that you are going to have more experts look more deeply into the issue. But obviously I, as a Minnesotan, should be a little bit bothered because Wisconsin hasn't done a heck of a lot about the acid rain problem.

You now come along with a cap and say we all ought to have caps; but as a practical matter, if we look at the Wisconsin record you are still up in the neighborhood of 2.4 to 2½ pounds per Btu—I hope I am not exaggerating, that was the figure I was given—compared to the folks with you on the panel representing the two States on your right and left who are substantially below you. But then, as others have said, we are differently situated.

I have a report from the Office of Technology Assessment which compares the energy tax proposal with the emission's tax proposal; and really for Wisconsin, it doesn't make a heck of a lot of difference to Wisconsin payers, in effect, which way you go. I think in Wisconsin the electric generation tax, 4.4 percent which is a percentage increase in electric rates, whereas if you use the emission tax approach, it would be only 4.1 percent. So actually your ratepayers would benefit slightly in Wisconsin from going to the emissions tax approach. In Minnesota—to prove I am not always parochial—that difference is 3.8 percent on electric generation tax versus 1.8 percent on an emissions tax.

Now, let me ask both you and Mr. Miller, if you were going to look at it a little more, I would like to have both Wisconsin and Michigan say that more explicitly. However, if you feel that just putting the tax on electric utilities and sending the bill only to the electric utility taxpayers, I need Wisconsin to justify that because I am bothered a little bit about it. I also need from Michigan a little bit more justification than I got from your statement.

Can I start with you, Mr. Besadny?

Mr. **Besadny.** Well, we are prepared to send you that background information. I felt because the time was short to prepare for this particular hearing that I wouldn't have all the details, but I am having my staff flesh that out right now and you will be getting our comments. I appreciate your comments on Wisconsin, and we are proud in our State of achieving fishing and swimmable water quality, but we acknowledge some problems with air.

As I said in the beginning of my testimony, we are probably more unique than Minnesota or Michigan in that we have more smaller older plants and that's what creates the problem. On an individual basis, I think you find that the emissions meet the air quality standards; but collectively from all sources we emit 726,000 tons of SO_2 per year. Now I see Michigan has dropped their emissions to that amount—I believe that was Mr. Miller's reduction point. We have an administrative rule that is going before our natural resources board and legislature in the next month or so to reduce some of the problems in our Green Bay area and also to significantly reduce those problems in Milwaukee. But certainly in a lot of peoples minds that is not enough. How we get reasonable reductions financialwise, I will have to defer to our economists.

Senator **Durenberger.** Thank you.

Mr. Miller.

Mr. **Miller.** We in Michigan have a lot of work to do yet, too, in terms of analyzing specific proposals for kilowatt taxes or whatever it might be to pay for the cost of acid rain control. And we have a new Governor in Michigan who is just starting to get into these issues. So in terms of specific position or statement on what kind of tax we like better than another, I can't make it here today.

What I was relating to you is experience that I have gathered particularly at our staff meetings, the State and territorial air administration. From all over the country we come together and we pretty much reflect our various States and the political atmosphere. And the only way we were able as a group to come to some consensus on acid rain was when we finally got to the point where we recognized that there needed to be some mechanism to help the States pay for the costs who have the big expense to undertake, the Ohio, Illinois situations. And that was the only way we could get to a consensus. And that's why I say it's a bitter pill, but we are going to have to swallow it.

In terms of the detail, likewise we want and need time to analyze specific proposals and would be happy to submit that analysis; and I would expect in the near future for the State to be taking a much more specific position on the issue.

Senator **Durenberger**. Let me make the observation that I appreciate the wisdom of what you just said as an approach. As an observation from 4 or 5 years in the U.S. Senate that none of the Senators are going to take anything other than a parochial position on these issues. They don't care about the national interest unless someone back in their State like you or your Governor or whoever says I am going to rise above my Michigan interest to a larger national interest, and then they are politically free to look at it nationally. So I certainly would encourage all of us to approach it on that basis.

When we talk about the despairities in these things, it is a matter of pointing out that they are real, there is a political dimension to them in terms of acceptance by taxpayers or ratepayers or feepayers or whatever that all of us have to deal with. So I think that's all of our objectives.

I need to get going, but I want to ask one question of our friend from Canada as long as I am picking on people.

Isn't it true that we look at mobile sources that Canadian tailpipes are a lot dirtier than American tailpipes; also that some of the Canadian powerplants are just as dirty as some of them in Ohio? I am told that might be true, and so my question is what is being done about it?

Dr. **Brydges**. The emissions standard for nitrogen on cars is higher in Canada, and again it's in response to historical problems. You have to lower yours to keep your own people from gasping and coughing to death. Because of our lower population and larger space, it wasn't a problem. You are talking about a historical problem on an acid rain problem the same way as we dealt with local SO_2 problems. And, of course, the nitrogen problem on the acid rain part we have given it a lower priority anyway. We do not see that nitrogen is contributing to the long-term acidification. So that's where that's at.

But I can also say that the Federal Government does have that under review and because of cars which are manufactured to be sold in the United States and are being sold in Canada, the average NO_x emission, in fact, is going down. Even though it isn't regulated, it is going down by reality because the cars are coming from the United States. So it's going down but it's because of historical situations; it's being reviewed.

Now, as far as the powerplants are concerned, it's exactly the same question. Historically those powerplants did not have local ambient air qualities. They had to meet those. Ontario Hydro has used washed coal for years which is purchased in the United States and keeps some of your coal miners working in Pennsylvania. I expect they may be higher than some U.S. plants in terms of emission while they were running. The other thing you have to understand with Ontario Hydro is they don't use the coal plants much. Ontario Hydro is going hydroelectric from water power and nuclear. However, they have a little trouble up there right now with a couple of the nuclear plants in shutting down, but essentially they are phasing out the coal plants and they will only be used for energy standby. So again it's a case of comparing apples to oranges. It's looking at the historical problem.

And the point I would like to leave you with is when we recognize that the long-range transport problem Ontario Hydro now has to meet of 43-percent reduction in those powerplants recognizing long-range transport. Does that clear that up?

Senator **Durenberger**. Thank you very much, and I thank all the panelists. We will be submitting some more questions to you.

Our next panel, Dr. Myron Uman who is executive secretary, Environmental Studies Board, National Academy of Sciences, Washington, D.C.; Mr. Gary Glass, Environmental Research Laboratory, U.S. Environmental Protection Agency in Duluth; and Mr. Jack D. Shannon, Environmental Research Division of Argonne National Laboratory in Argonne, Ill.

I take it we have statements in advance from all these witnesses which will be made part of the record, and the statements may be abbreviated or read as appropriate.

I am not clear, Gary, whether or not you are testifying today on behalf of the EPA or not. I know who you are employed by in this sense, but I can't tell for sure whether they have authorized you to speak for them here today.

What is the status?

Mr. **Glass**. I think the latest word is I have received an approved document that I distributed that had a paragraph inserted that I can comment on when it's my turn to speak. But since they—EPA—paid my own way down here, I am here as a laboratory scientist on official duty to give you the best technical information that I can provide. The EPA standard for this type of information is that the disclaimer for policy implications is in effect: anything that I might say, at this time, that has policy implications does not have official agency endorsement.

Senator **Durenberger**. Dr. Uman, we welcome you here and we look forward to your testimony.

STATEMENT OF DR. MYRON UMAN, EXECUTIVE SECRETARY, ENVIRONMENTAL STUDIES BOARD, NATIONAL ACADEMY OF SCIENCES

Dr. **Uman**. Thank you, Senator, I will try to be brief.

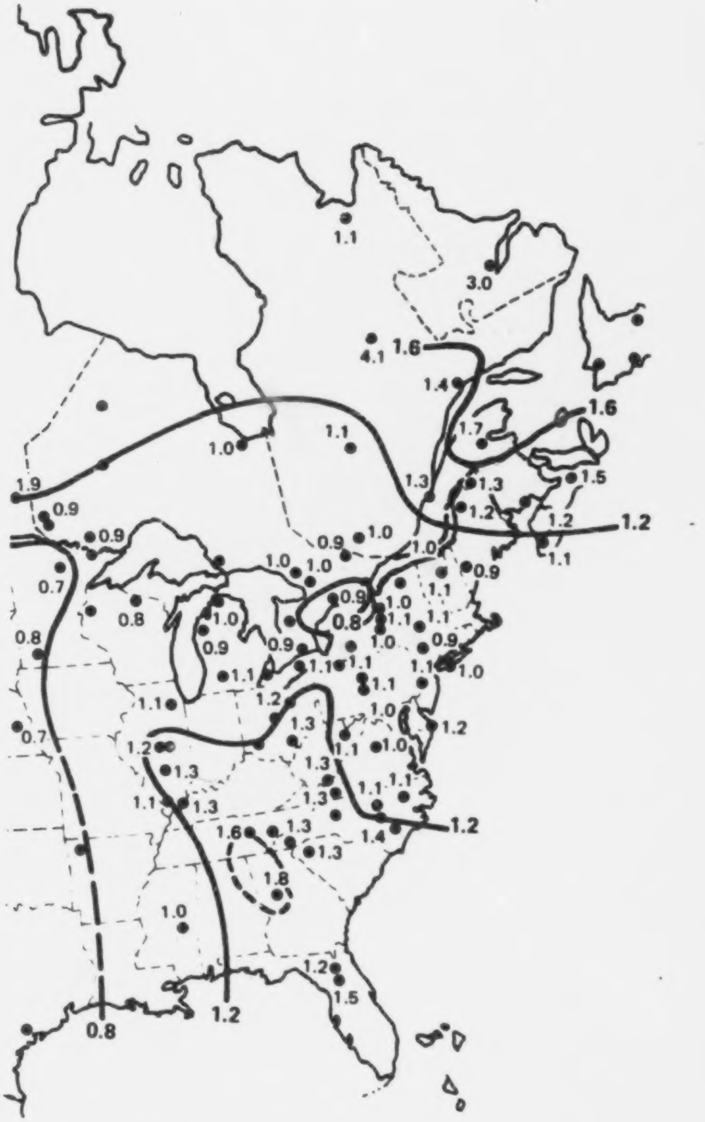
First, let me apologize for Jack Calvert, chairman of the Academy's Committee on Atmospheric Processes in Acid Deposition; he is unable to be here today. We appreciate very much your interest in the Academy's report, and I will try to answer whatever questions you have about it.

Now, let me give you a very brief background about why we organized our study. In 1981, another committee of the National Academy of Sciences issued a report called "Atmosphere-Biosphere Interactions Toward a Better Understanding of Ecological Consequences of Fossil Fuel Combustion." That report concluded, based on studies of sensitive lakes ecosystems, that a 50-percent reduction in the deposition of hydrogen ion to sensitive areas in the northeastern United States and southeastern Canada would be desirable to prevent damage to those lake ecosystems. That conclusion was misinterpreted widely in the press and elsewhere as a call for 50-percent reduction in SO_2 emissions. The recommendation was for a 50-percent reduction in hydrogen ion deposition. The deposition of hydrogen ion is associated generally with sulfuric acid and nitric acid. In the meantime, since the issuance of that report in 1981, there appears to be more concern with sulfuric acid, at least for long-term acidification effects.

In late 1981 when this report was issued, the following question arose within the scientific community: If we want to have a 50-percent reduction in hydrogen ion deposition, what, in fact, would be the required reduction in emissions of precursor gasses. At that time the only data that had been analyzed were from Europe, and those data suggested that there was a strongly nonlinear relationship between emissions of precursor gasses and the deposition of acids or acid forming materials. In that circumstance a very substantial reduction in emissions would be required for a moderate reduction in deposition. So the committee was organized to see what data were available in North America to analyze this problem.

The situation in eastern North America, meteorological and climatological conditions, distribution of sources, and so forth, are different from those in northern Europe, and so we set about to determine whether, in fact, a strong nonlinearity in the relationships between emissions and deposits of acid existed in eastern North America as it appeared at that time to exist in Europe. The committee looked at the data in several ways. First, they compared very good data on wet deposition of sulfate and nitrate from a series of networks that have been set up very recently in the United States and Canada. And for these data I refer you to exhibit A, which is figure 4.17 of the Academy's report. We also looked at the historical record of deposition of total sulfate and nitrate at the Hubbard Brook Experimental Forest in New Hampshire. For the Hubbard Brook data see exhibit B, which is figure 4.19 in the report. We looked at other long-term time series, but in detail concluded that those data were not reliable, or at least not as reliable as the Hubbard Brook data. We also reviewed recent laboratory studies using cloud chambers and other types of studies that were done under experimental conditions which reflected the real atmospheric conditions in eastern North America. And we also examined available theoretical models of the relationship between changes in sulfur emissions and changes in sulfur deposition, and for that I suggest you look at exhibit C, which is adapted from figures 3.1 and 3.2.

[The exhibits referred to follow:]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$\frac{SO_4^=}{NO_3^-}$ in Precipitation (1980)

Exhibit A

Figure 4.17 from Acid Deposition: Atmospheric Processes in Eastern North America. Washington, D.C.: National Academy Press. 1983.

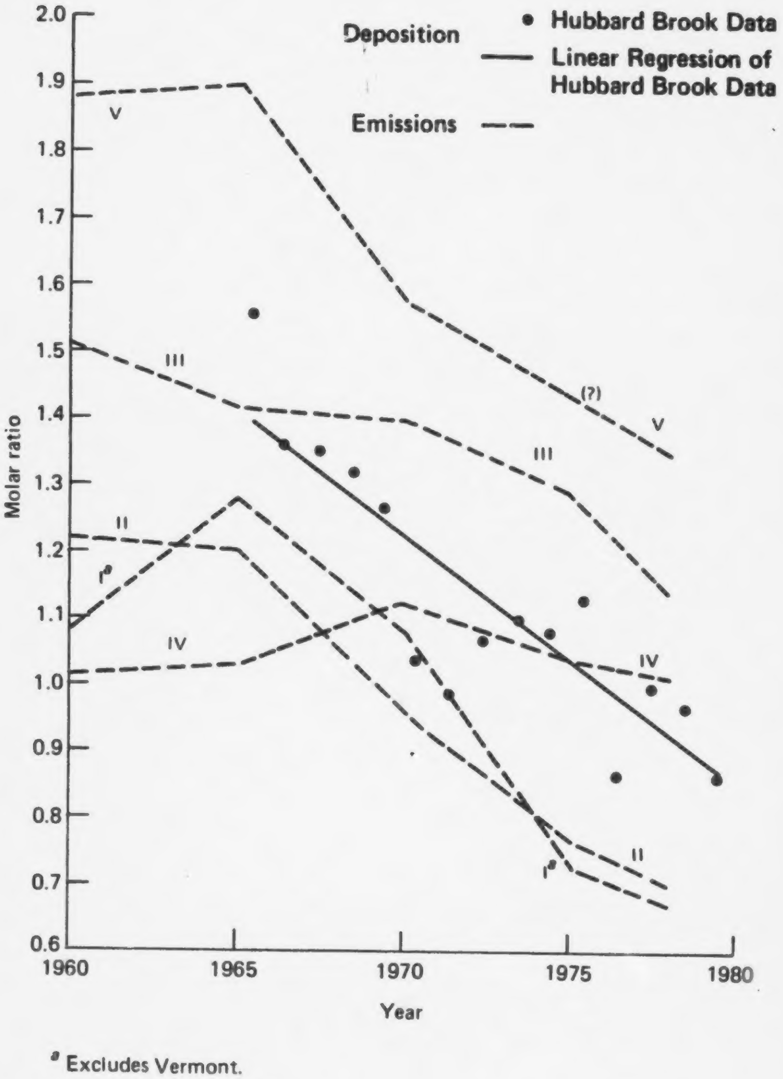
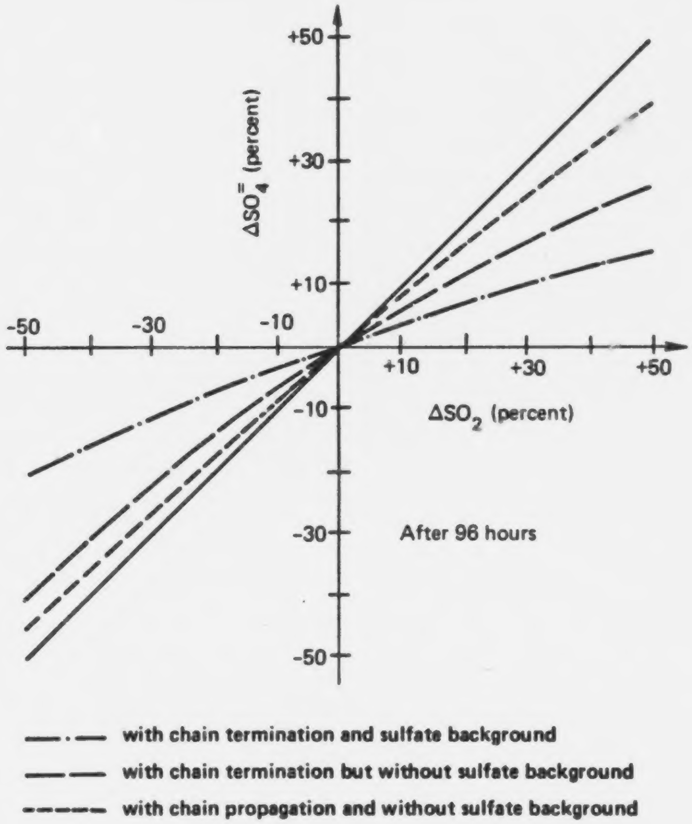


Exhibit B

Figure 4.19 from Acid Deposition: Atmospheric Processes in Eastern North America. Washington, D.C.: National Academy Press. 1983.



Calculations Using the Sampson (1982) Model Based on that of Rodhe et al. (1981)

Exhibit C

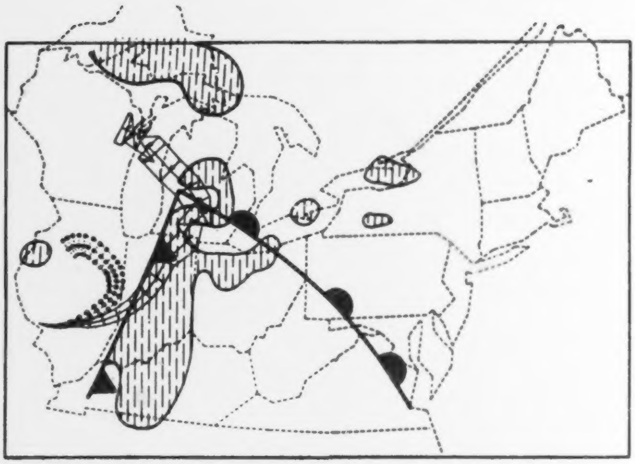
Adapted from Figures 3.1 and 3.2 of Acid Deposition: Atmospheric Processes in Eastern North America. Washington, D.C.: National Academy Press. 1983.

Dr. UMAN. The finding of the committee was that there is no evidence for a strong nonlinearity in the relationship between emissions of sulfur dioxide and deposition of sulfate as sulfuric acid in eastern North America if one averages over a period of a year or more and includes all emission and all deposition in eastern North America. That's as much as we could find to say.

When one looks at a smaller scale and tries to determine transfer functions from the data—that is, the relationship between emissions in one small location in eastern North America and deposition of acid in another small portion of eastern North America—we do not have sufficient data to be able to analyze for those relationships statistically. We are faced with doing it theoretically. So we looked at a variety of long-range transport models, that is, models for the atmospheric processes which transport pollutants great distances and result in their deposition. After looking at the models that are currently available, the committee concluded that the models, while useful in a qualitative sense, are not quantitatively reliable and sufficient for regulatory purposes—or what the committee interpreted as regulatory purposes.

By and large, the models do not reflect what current understanding of the complex chemistry of the atmosphere is all about. They, by necessity, use approximation for both the chemistry and the physics. In the treatment of transport processes, various assumptions can be made; and by making one assumption or the other, great differences can occur in the results. And as an example of that, I refer you to exhibit D, which is figure 2.3 of the study.

[Exhibit D follows:]



Calculated 24 Hour Trajectories

.... assuming isobaric motion

—— assuming isentropic motion

Exhibit D

Figure 2.3 from Acid Deposition: Atmospheric Processes in Eastern North America. Washington, D.C.: National Academy Press. 1983.

Dr. **Uman**. In general most of the models—and here I have to say that there is a very strong attempt to correct this problem going on now—do not account for large scale weather systems including clouds. And as an example of the influence of clouds and weather systems I refer you again to exhibit D and also to exhibit E, which is from the recent NAS report.

[Exhibit E follows:]

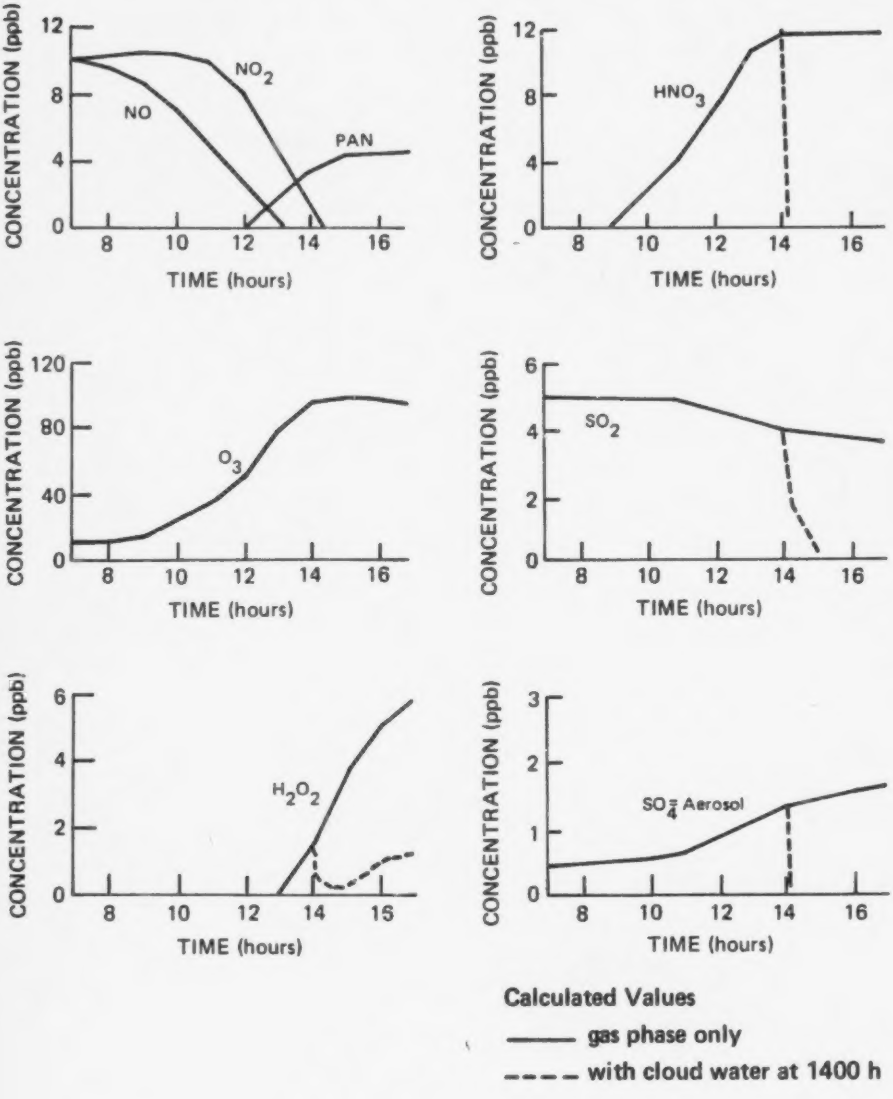


Exhibit E

Figure 2.7 from Acid Deposition: Atmospheric Processes in Eastern North America. Washington, D.C.: National Academy Press. 1983.

Dr. UMAN. Finally, the committee concluded that the models have not been validated. While many of the models agree in their results, qualitative and quantitatively, within a factor of 4, it is not clear that that level of precision is sufficient.

Now those are the two results of the committee's report: One, that there is no evidence of a strong nonlinearity in the relationship between average emissions and deposition; and two, that at this time we do not have sufficient information to be precise about detailed relationships between specific sources and specific reception sites. May I say in passing that the panel chaired by Bill Nierenberg and organized by the Office of Science and Technology Policy came to the same conclusions independently.

What are the implications of these results? I wish to tread lightly here because I do not want to be misinterpreted. The committee concluded that of all of the control strategies that one might think of, there is a high degree of confidence in analyzing only one of them. In stating what our conclusions are about that one possible control strategy, we do not wish to infer that this is a recommended control strategy. I want to be very clear about that. The National Academy of Sciences and its committee does not recommend a uniform rollback. It does not recommend anything. The committee did not study cost/benefit relationships or any of the other factors that one ought to study before recommending a control strategy. The report merely says that we can only analyze the consequences for deposition of the uniform rollback strategy.

Now, by uniform rollback strategy we mean a strategy in which emissions of sulfur dioxide are reduced on a percentage basis equally State by State and Province by Province throughout eastern North America. Under those circumstances we would suspect a proportionate reduction in deposition of sulfate and sulfuric acid, in the same region of eastern North America everywhere by roughly the same percentage, within 10 percent. Again, the panel formed by the Office of Science and Technology Policy came to the same conclusion.

The committee further concluded that research and development to improve the base of data so that one can make more detailed assessments, for example of a detailed pollution control strategies where emission reductions were not taken uniformly, would take some time. There are various approaches that could be taken; but in the committee's informal opinion it would be unlikely that new results from these approaches would be available with the same degree of confidence as the current result of 4 or 5 years—and that assumes vigorous research and development programs.

Perhaps I should conclude my testimony at this point. If you have any questions, I would be delighted to attempt to answer them. Thank you.

Senator DURENBERGER. Thank you very much.

Mr. Gary Glass.

STATEMENT OF GARY GLASS, ENVIRONMENTAL RESEARCH LABORATORY, ENVIRONMENTAL PROTECTION AGENCY

Mr. GLASS. I must say I am pleased to be here even though I was on holiday like some others here but did, in fact, put this statement together over the last few days in a way in which it can be used as a statement and documentation of what we have learned to date. It's a summary of the 36 publications that we now have in press and that have been approved for publication, and it also shows the additional 20 publications and their titles that we expect to complete over the next year primarily due to your hard efforts and getting the funds restored to the Duluth program and its cooperators, University of Minnesota, Wisconsin Department of Natural Resources, U.S. Forest Service and others are the beneficiaries of that and I will be allowed to complete the analysis of the fourth year of the program.

I might add and also to comment that the fifth year of the program at this time has not yet been funded. It would go to answering some of the questions that were brought up by the representative from Michigan where we had planned a technology transfer from the 56-plus documents that we will have in place after our data gathering is completed and the synthesis published to transfer the knowledge into the individual States for their own individual agency uses, and to tailor that type of information in a way in which it will answer the specific States' needs. I agree with the representative from Michigan that the largest lack of information that we have in all three States does exist in Michigan. The report I have here does indicate that there is very strong reason to do that work in Michigan.

So what I would like to do because we are running late is simply not try to read this 40-page document but simply skim the highlights. I received last night at about 11 o'clock a new package of my approved written statement with a beginning paragraph that has been inserted by someone in Washington which contradicts the fifth paragraph explicitly. So I have made a mark on that paragraph so you can see the errors which are not correct. (See p. 105.)

Senator **Durenberger**. Can we skip 2, 3, and 4 as well?

Mr. **Glass**. No, I believe that all the words starting with "This statement has been prepared in response . . ." are written by me, and the one that precedes that is not.

The request was that I would bring forward to this group, the Senate subcommittee, the peer-reviewed, published, hard data that's in the literature, and that we have from within EPA's research lab at Duluth, and its cooperators, the State agencies which are part of the program that Ms. Gardebring and Mr. Besadny and others have referred to. We have been working with these State resource and regulatory agencies for more than 3 years now gathering this data as the best hard science that we know how to do. We have just gone through, within the last month, the 10th peer review of the Duluth lab's acid rain research program and came through with grades from very good to excellent on the quality of our science and its relevance. So there should be no question that the references 1 through 36 that I have listed here are, in fact, peer-reviewed information and should stand the test as high-quality science.

My interpretation of the information in this written statement is one of, as I see it, a personal consensus with the peer scientists which I am representing. So in addressing the four questions that I was asked to respond to, one being the nature and extent of the areas within the upper Midwest sensitive to acid deposition, I reiterate what we have found. And the bottom line is that the upper Midwest, these three States, have more sensitive lakes than the Northeast, and that's covered by other reports including the OTA office report. In these three States the problem is that we have more to lose than the Northeast. We haven't lost it, but, in fact, it's there potentially to be lost. And Wisconsin I would say is the State that has the most to lose of the three States because it does have more lakes than any of the others that we found to have very low acid-buffer capacity. So if the precipitation quality were to continue to be as acid as it is or to be increased, all of our data at this time indicates that those lakes clearly would show alteration and eventually show resource loss. So in terms of addressing your first subject or question, I believe that we have done that and I won't go into anymore detail at this point.

Another factor that would relate to the susceptibility of these sensitive systems is the up-wind energy development that is occurring that is unique to this area of the continent, figure 9. The upper midwest has to look to the areas to the west; and so if this country had developed historically on the west coast, instead of the east, we would now be the Adirondacks of North America at this time because most of that deposition would have fallen on us. So the future solutions to our problem of protecting the resources will have to look at the emissions that will be generated in the west as those energy resources are developed.

The present situation in this region is outlined on my pages 3, 4, and 5 and substantially in the figures, and I am not going to repeat that now. But if one looks at the other parts of the world receiving equivalent acidic deposition to what this region is getting today, there is some very serious potential problems. Northeastern Minnesota is receiving precipitation as acidic as a site in Norway where there is a documented loss of fisheries. The difference being perhaps the more recent onset of acid precipitation in this area as compared to Scandinavia, but there is no question in the minds of world class scientists that the differences between the two areas are: one, the time in which the acid deposition has started, earlier there than here and; two, the sensitivities of the areas, northeastern Minnesota being slightly less sensitive than some of the areas of Norway. It was felt that the loading is sufficient to cause alteration if given enough time.

As I look toward the east (figure 10) and the acid deposition gradient increases, that impacts becomes much more a matter of probability in the near term; that is, the eastern end of the Upper Peninsula of Michigan is receiving acidic deposition where there is almost no question that the sensitive lakes there have already been eliminated in terms of lost alkalinity, and those remaining are probably in a State of change at this point in time.

Now, the various sources of that change have been and are under study at this point in time, and we look to this next year to refinalize our conclusions on what has been the reason for the alterations and changes of those lakes. But if you use the world literature to make a comparison, there is almost no question that the 12 percent of the lakes that we found in the Upper Peninsula to be acid, that many of those will be, in fact, categorized as acidified, having been altered.

The other parts of the question that Tom Brydges spoke to us about is that you can't simply isolate acidic components in the absence of other kinds of contaminants is very true. And that very recently we found by monitoring the mercury in rain, very high levels of mercury were measured, higher than what one would have in water to protect the resource of that water, exceeding EPA criteria for limiting mercury in fresh water; above 200 parts per trillion. And how can you have fresh water, being of good quality, when it's recharged from the atmosphere and it is already contaminated. So one has to have a mechanism to keep the media of water purification, the atmosphere, clean from causing those contaminants from entering into the recharge of our lakes and streams.

Additional studies that we have just completed in Wisconsin indicates that the water quality of some of the lakes that have no other source of recharge but the atmosphere, the mercury in those lakes is very high and would most probably account for the elevated mercury values in fish that Mr. Besadny spoke to as exceeding FDA standards at this point. And again the world literature indicates that the acidity of the atmosphere plays a role in scrubbing out mercury, mercury being a volatile element. It appears in the atmosphere as a gas, is oxidized and it has some alkaline or base characteristics that when combined with acid rain will cause it to be scrubbed. So the increasing acidity can, in fact, play a role in the more efficient scrubbing of mercury out of the atmosphere. So that's a whole different topic, but I want to alert you to the other traits of the atmosphere that cause pollutants to move through it. It's simply not sulfur emissions are the problem; it's many places where we have used the atmosphere as a waste disposal medium. And we are now bearing the cost of not keeping the hydrocycle—hydrologic cycle of water—clean which includes both air and water.

I think the last topic that I was going to address addresses the area of reduction of impacts. And I think that when we look to where is the acid deposition coming from, many people have focused on wet acidic deposition only as being the thing of concern because it is easy to measure. Dry deposition, because it's difficult to measure, its tended to be overlooked. And I wanted to point out that through a cooperative study with Ontario and the Minnesota Pollution Control Agency at a site in the Boundary Waters Canoe Area, we have a site that is measuring both wet and dry deposition. It's a highly technological site where Ontario has located one of their sampling stations to participate in a cooperative study. This type of sampling technology needs to be located in other areas to verify the modeler's projections that you can have a major proportion of the total acidic deposition being deposited in the dry form. This information points to a conclusion that small dirty sources that perhaps don't contribute in a major way to massive transport or international boundary transport, do in fact, contribute in a major way to the local areas 3-day deposition.

I have one particular figure (figure 11) that shows the emissions sources in northeastern Minnesota as they contribute to the deposition in Minnesota. And we can, in fact, account for perhaps an increase of more than 100 percent of acidity due to the dry components from within our own State from close sources that have very low stacks burning fairly high sulfur fuel. So what one has to look at is the total problem of what the watershed is receiving, not just looking at what the rain scrubs out but also, during the time it is not raining, at the gasses in the atmosphere that are depositing acids in terms of fog, mist, dew, particulates. Those are the kinds of considerations that should be kept in mind; that it's a total accumulation of all airborne deposition as it acidifies the resources we are trying to protect.

Senator DURENBERGER. Thank you very much.

Jack Shannon.

STATEMENT OF JACK D. SHANNON, ENVIRONMENTAL RESEARCH DIVISION, ARGONNE NATIONAL LABORATORY

Mr. SHANNON. I am a modeler of long-range transport and deposition; that makes it pretty convenient for me to be sitting up here next to Myron.

This is an important question. How good are the current models of long-range transport and deposition? If emission control legislation is enacted in the next year or two, current models are going to be used if any models are going to be used because the models under development are going to produce results somewhere farther down the line.

There is no monitoring nationwide of dry deposition. Gary just mentioned a specific instance of monitoring. You can go out and measure dry deposition in careful field experiments, and there are plans to develop monitoring networks; but right now it's just wet deposition that's actually monitored. As one of my former bosses used to say, if you just have a bucket out there collecting the dry part, the big question is whether you measure what's on the inside of the bucket or the outside of the bucket.

In comparing my own model results for annual deposition of nitrate and for annual deposition of sulfate for 1980, the entire year, with observations from roughly 100 stations in the United States and Canada from the various major networks, I found that my model could explain about 75 percent of the observed variance in both cases. And I think there are some other models that could do a comparable job. Every modeler feels his own model is best, but I wouldn't think that mine is head and shoulders above the others.

The 25 percent unexplained variance is not entirely model error per se because verification calculations are made under the assumption that the emission are correct. Well, having worked with several emission inventories somewhat interchangeably in the last several years, I know that the major inventories contain large differences for particular States. As examples, there are 50 percent differences in the total emissions for New York in the major inventories. For Illinois, differences are even larger. The model is just the relationship between emissions and deposition. In model evaluation one assumes that input is correct and one assumes that the ambient measurements are correct, but that's not precisely true. However, even though the model can do well simulating annual deposition, that does not prove that it can do equally well on the deposition from a particular source or source region because verification measurements are for the effects of all sources, but at least it is encouraging.

One of the problems in assessments using current models is that almost always there is not a long enough period of meterological record going into the model runs. For instance, in the MOI evaluations which were the only thing considered in this——

Senator DURENBERGER. This is the reference to the National Academy?

Mr. SHANNON. Yes.

Several of the models had available at that time just 2 months of meteorological data in 1978, one of those months being January. In January in the northeast and along much of the Atlantic coast precipitation was more than double the climatological norm. The source/receptor transfer matrices calculated by the models for those periods are now being used quite a bit. And I fear that they are actually being misused because the effect of New York on New York is going to look much greater, because it was raining so much there, than it would in a normal case. At the same time it was raining so much in the Northeast, the upper Mississippi Valley was extremely dry. It is important to have a long period of record in simulations in order to have a good expectation for future conditions.

One of my coworkers at Argonne, Dr. David Streets, used my source/receptor calculations to analyze some of the legislative proposals. He first took the reductions mandated by the proposals as written and converted that to emission reduction per State, assumed a uniform reduction and quantified that in terms of dollars and in terms of how much sulfur deposition would be reduced in the Adirondacks—as a case study he was looking at just one receptor area. He had a data file of major sources and how much it would cost to cut various levels of emissions at each of the sources. For instance, if you have a plant that's burning high-sulfur coal, it's going to cost you a certain amount to convert to low-sulfur coal, and a different amount to install a scrubber. He could quantify the direct cost of the emission reduction in that way. He then did a least-cost emission reduction across the 31-State area, with calculations indicating even more deposition reduction in the Adirondacks than would result from a uniform emission reduction across the 31-State area, but for a cost of only a fraction of the original presumed cost of the legislation. He further tested strategies to reduce the deposition in the Adirondacks by the same amount as each of these bills but at a minimum cost. He found that the overall emission reduction required was about one-half of that in any particular legislative proposal and the cost was about one-fourth. In his analyzed costs the differences were between $3 billion and $10 billion a year.

Now, as a technique I think that shows great promise. As a particular result, it is, of course, quite limited because the study does not address sulfur deposition changes in other sensitive areas such as the Boundary Waters or the Smokies. If you are only interested in reducing the deposition in the Adirondacks, Missouri is not going to make much difference, Minnesota is not going to make any difference—I mean you are going to have to print out several digits to show Minnesota's effect—so on a cost effective basis considering only the Adirondacks, you don't reduce emissions in Minnesota or other States west of the Mississippi, even though these sources can affect the Boundary Waters quite a bit. For this technique to be used in policy analysis, I think it needs to be applied to all sensitive regions as defined by people like Gary Glass; and I think then that we can combine our knowledge of economics and our knowledge of atmospheric processes—of which we do know a great deal—and our knowledge of ecological effects, and make some choices that would be extremely cost-effective in comparison to decisionmaking ignoring any one of those particular disciplines. It is difficult to do interdisciplinary studies. Each person always thinks his own work is very complicated and tries to oversimplify the other areas.

I heard some estimates a while ago of the effect of different sources upon the Boundary Waters and upon Minnesota, and I happen to include such calculations in my written report. As was stated, the largest single State contributor to deposition of sulfur in Minnesota is Minnesota. The largest contributor to deposition in Wisconsin is Wisconsin. In general, the major emitter States in the Ohio River Valley contribute about 35 percent of their own deposition. States with lower emission densities contribute about 25 percent of their own deposition. In my calculations Wisconsin contributes a bit more than 25 percent, Minnesota a bit less. Some of the Northeastern States that have very little industry contribute a very small percentage of their own deposition. About the only States that do the lion's share of their own deposition are either the west coast States, because they are upwind, Florida, because it is a peninsula, or Arizona and Texas, partially because they are upwind and partially because they have some significant smelter sources in their southern regions.

The wet deposition calculated for the Boundary Waters from all sources can be compounded with observations for 1980. Wet deposition from anthropogenic sources, United States and Canada, for the Boundary Waters was calculated as two kilograms of sulfur per hectare per year or 6 kilograms of sulfate per hectare per year. Two nearby monitoring sites plotted in the National Academy report show measurements of 6 and 7 kilograms of sulfate per hectare. Model results are close to what is observed in this case.

The simulations also show that the local contribution to deposition is greater for the dry share, and additional calculations (not shown) indicate that North Dakota sources deposit more sulfur on Minnesota than Ohio sources. The latter result is due to North Dakota's proximity to Minnesota. I didn't even include Ohio in the table I produced here because it has very little effect on Wisconsin or Minnesota or the Boundary Waters. I didn't include Michigan in my receptor calculations; had I done so, of course, you would see a significant effect there from Ohio sources.

My calculations and what they imply about what could be gained in terms of deposition reduction if there is an emission reduction assume that the same linear approximations now used in the model would still hold, but that remains to be proven by field experiments.

Thank you.

Senator Durenberger. Thank you very much. Just for starters, do any of you want to comment on the testimony of the other witnesses?

Dr. Shannon. I would like to make a couple of comments.

One is that the National Academy study included no discussion of the European data except in very general terms. Those general terms might be correct, of course, but the same laws of physics and chemistry apply in North America as in Europe. Thus, if the processes are linear on one continent and nonlinear on the other, there must be a physical or chemical reason and the report doesn't really resolve that.

I feel that there is a good deal of field work that could examine the linearity question, and I have some interest in that. There are several proposals to do so now circulating.

Dr. UMAN. That I will respond to.

Senator DURENBERGER. Fine, do.

Dr. UMAN. The committee did not investigate the differences between North America and Europe with regard to acid deposition because its charge was to deal with the data in North America, and they had a limited amount of time and a limited amount of funds to do the study. But they did conclude that there are basic differences in the two situations which plausibly could explain the differences in the phenomena. One of these is that the area of Europe we are talking about is farther north in latitude than the areas of North America that are subjected to highest and most intense acidity. The processes are photochemically driven, so they depend on the amount of sunlight, which is greater at more southerly latitudes.

Also, eastern North America is generally subjected to alternating regimes of continental polar air and maritime humid air, whereas northern Europe is almost always in a maritime regime. There are differences in the spatial distribution of sources as well.

So there are a lot of reasons why one might expect differences between North America and Europe.

Senator DURENBERGER. Let me just read the conclusion for you, the finding on page 8 of your testimony, Dr. Uman. And maybe by way of amplification and clarification and reaction by you and the other panelists—it says:

> Our findings, while important, have only limited applicability. We believe the report demonstrates that a uniform reduction in emissions of SO_2 would lead to a proportionate, uniform reduction in deposition of sulfates (with a constant of proportionately close to 1.0). We do not intend by this statement to imply that the policy of uniform emission reduction is the best one to adopt. Obviously, recommendations on control policy should be based . . .

Et cetera, et cetera.

Does that imply that if reductions are not uniform—in other words, if we have 50-percent reduction in some areas and zero percent reduction in other areas, would you or your colleagues be unsure what the results would be in terms of deposition?

Dr. UMAN. Let me answer that if I may with more than a yes or no, and I think this will be helpful.

The short answer is we would be more uncertain. There are a variety of control strategies that one can conceive of and there are risks and benefits associated with each control strategy. And let me focus on an unusual aspect of risk and benefit, which is the risks and benefits of the control strategy working. If we can for a second focus on that. There are certain control strategies—and this uniform rollback is one of them—in the opinion of this committee where the risks of it working are low. Conversely there is a very high degree of confidence that a uniform roll back strategy would work. It will provide the benefits in the areas where you need the benefits. Other control strategies, because they are based on less certain types of analyses, entail higher risks for them working.

Senator DURENBERGER. Risks of them not working or working?

Dr. UMAN. Risks that they would not work.

One can think of both more expensive control strategies and less expensive control strategies, so uniform rollback strategies is not the most expensive; it clearly is not the optimal strategy. The optimal strategy would be one in which we can select sources or source regions that are most important for the most sensitive areas and control them selectively if, in fact, it's politically possible to do that. But the current state of affairs in our understanding is that there is greater risk that such a program would not work. We cannot be sure that controlling those selected sources is actually going to result in reduced deposition where we really want it. So in some sense, while we know the uniform rollback strategy is not the least expensive, we are paying some extra if we want to do a uniform rollback strategy. And again, I am not suggesting that we do.

But you can think about it in the following way: Dr. Calvert, in a press conference, said he would guarantee that if there were a uniform rollback strategy that you would get a reduction in deposition in the sensitive areas. But you also get a reduction in deposition in the areas that are currently regarded as not sensitive. The extra amount you are paying for that strategy is for reducing sulfate deposition in places where people don't care, at least about acid rain. It would have other benefits of course; one has to to do with improved visibility for which there may be substantial benefits on a regional basis.

Senator **DURENBERGER**. And you would advise us not to lose sight of the fact that we ought to look beyond acid rain?

Dr. **UMAN**. I think that's true.

Senator **DURENBERGER**. Anybody else want to comment on the matter of uniform rollback and cost benefits?

Dr. **SHANNON**. Yes, I agree there is a higher risk that the nonuniform rollback will not work precisely as expected. That doesn't mean that such a strategy will not work. Maybe the strategy would be only 90 percent as effective as expected, while costing half as much as a uniform rollback. It would seem to me that that is cost effective.

Senator **DURENBERGER**. OK.

Gary.

Mr. **GLASS**. I would like to at least notify you that picking a target loading as an answer that people will then run their models against does haave implicit within it the compromises that you will, in fact, have to give away the ultrasensitive resources, particularly some of the most sensitive terrestrial organisms and perhaps some aquatic organisms. You should be aware of that when you make that judgment on loadings particularly when you are trying to keep a wilderness area intact. That 20 kilograms per hectare per year of wet sulfate deposition will not, in fact, protect the wilderness area from perhaps some substantial changes and that the actual process of coming up with a compromise level of acidic loading should evaluate very carefully the ultrasensitivities of certain parts of the ecosystem that are not, in fact, recognized at this point in time. Some more information and research will point out more sensitivities and so a compromise loading at this time should be reviewed as more data is developed particularly in high sensitive areas.

Senator **DURENBERGER**. Dr. Uman.

Dr. **UMAN**. One final comment on Jack's last statement.

I think he is absolutely right. He said that there is more uncertainty associated with highly targeted control strategies at the current time. Perhaps I should express the caution, if I may, to be concerned about exacerbating that problem within a phased approach to pollution control for acid deposition. That is, if there is a first phase in this process which has a small or modest reduction in SO_2 emissions, it might be very difficult to observe the reduction in deposition of sulfate. One has to be careful that the first phase of the program is sufficiently large that we can have confidence in seeing the result. There is a variety of reasons why we might not see the result, one being climatological variability and the other being uncertainty in the models.

Senator **Durenberger**. I have a number of questions including several from my colleague from Montana that I am going to have to submit to each of you in writing for the sake of time. We are all indebted for you being here and for the work that you represent and look forward to working with you in the future as we address the problems that brought us to gether today. Thank you very much.

Our last panel includes Mr. Michael N. Gregerson who is the manager of Environmental Sciences for Northern States Power Co. of Minneapolis; Mr. Edward Bartlett of the legal department of Montana Power Co., Butte, Mont.; Ms. Elizabeth Barrett-Brown, National Clean Air Coalition, Washington, D.C.; and Mr. Steven Ring representing the Sierra Club in St. Paul, Minn. I welcome you all.

I really hate to do this in light of the importance of your observations, we are using a 10-minute ground rule. If there is any way for any of you, without diminishing the import of what you have to say, to reducing your 10 minutes to something less than that, be assured that your full statements will be included in the record and would be appreciated.

So we will start with Mr. Gregerson.

STATEMENT OF MICHAEL GREGERSON, DIRECTOR, ENVIRONMENTAL AND REGULATORY ACTIVITIES DEPARTMENT, NORTHERN STATES POWER CO.

Mr. **Gregerson**. Thank you, Senator.

My name is Michael Gregerson. I am director of the environmental and regulatory activities department for Northern States Power Co., and I have agreed to testify for your committee on our emissions picture for Northern States Power Co. and in response to some of the proposals that have been put forward.

About 43 percent of NSP's electric generation is produced by five major coal plants ranging in size from 275 megawatts to over 1,400 megawatts. NSP also operates 1,550 megawatts of nuclear generation and has a major purchase agreement with the Manitoba Hydro-Electric System.

The first issue I would like to address is NSP's historical emission rates. In 1970 NSP operated seven coal plants with combined sulfur dioxide emissions of approximately 235,000 tons per year. By 1980, we managed to reduce those emissions with the help of the Pollution Control Agency to about 105,000 tons per year. So in 10 years we were able to cut our emissions by more than two-thirds. And I think an important fact here may be in contrast to the Canadians is that we accomplished those reductions without a decrease in coal-fired facility production. In fact, coal-fired energy production increased significantly over that 10-year period.

NSP's two newest and largest units at Sherburne County operate below 0.7 pounds SO_2 per million Btu. And these major reductions in sulfur dioxide over the entire NSP system resulted in a systemwide average emission rate of about 1.5 pounds per million Btu. We estimate that these reductions were accomplished at a cost of over $300 million to NSP's ratepayers.

I think an important question to these proceedings going on here and everywhere else is what type of control alternatives should be used to reduce SO_2 emissions. Every NSP coal-fired powerplant burns from 80 to 100 percent low-sulfur western coal. Sherburne County Units 1 and 2 burn 100 percent low-sulfur western coal and employ flue gas desulfurization systems known as wet scrubbers. These scrubbers reduce sulfur dioxide concentrations by 60 to 70 percent and particulate concentrations by over 99 percent. At NSP's Riverside Plant, units 6 and 7 have been retrofitted with a new technology known as dry scrubbing, reducing sulfur dioxide concentrations by 70 to 80 percent. NSP plans to develop an experimental fluidized bed combuster at its Black Dog Plant.

NSP's newest facility, Sherco 3, began construction on August 15. This unit will be NSP's largest coal-fired powerplant, over 800 megawatts jointly owned with a number of municipals in the State, and will employ the latest control technology and be one of the Nation's cleanest plants.

If I could summarize our efforts to date and concern for the future, it is this: NSP has employed all of the reasonable SO_2 control options available at each of our facilities. Will we be allowed credit for the major improvements we have made, or be taxed and controlled without regard for these accomplishments. And I think that's been addressed by a number of speakers before us.

And now on the legislation. A number of Senate bills call for about a 10 million ton reduction in sulfur dioxide emissions from the 31 States east of or bordering the Mississippi River. For Minnesota, this results in a required reduction of about 65,000 ton per year. NSP's fraction of these statewide reductions is approximately 45,000 tons per year. As mentioned earlier, only scrubbers could be installed to make these reductions. Costs for the scrubbers would be approximately $230 million and result in rate increases over $70 million per year.

Congressman Waxman and Sikorski also have proposed a form of national acid rain legislation. This bill also requires a reduction in sulfur dioxide emissions of 10 million tons per year from coal-fired powerplants. Approximately 63,000 tons per year in reductions are required for Minnesota. Of this total, NSP estimates approximately a 40,000 ton reduction for the NSP system. Two scrubbers would be required to make such a reduction, and would cost NSP customers approximately $70 million per year annual revenue requirements. In addition to the emission reduction requirements, the Waxman proposal imposes a 1 mil per kilowatt hour tax on the sale of nonnuclear generated electricity. This tax would cost NSP customers an additional $18.5 million per year. These funds would be used to pay for scrubbers and other control techniques in the most heavily populated areas of the Midwest. Under the Waxman proposal, NSP customers, who have already paid to clean up the NSP system, would pay again for additional expensive scrubbers and a third time for controls in other parts of the country. These additional costs over and above NSP's existing investment in pollution control would result in increases of $25 to $30 per year for the average residential customer.

Finally, NSP believes that the Federal funding mechanism must be based upon pollutant emissions. A tax on sales discriminates against utilities that produce substantial energy at low pollutant emission rates.

NSP favors acid rain control legislation and supports control of existing sources now. But we also believe that any national legislation must be equitable, must be effective and it must be achievable.

If a national tax is necessary, we strongly favor a pollution tax versus a kilowatt hour fee. We also favor a national bill and support control of all pollution sources which may affect the acid rain chemistry picture.

Finally, no bill to date gives incentives for replacement of older coal-fired powerplants with clean, efficient units such as Sherco 3.

We believe that the regulatory framework in Minnesota and the efforts of NSP and other Minnesota utilities over the last 10 years serve as good examples for national legislation.

Thank you.

Senator DURENBERGER. Thank you very much, and let me congratulate my home town utility. As far as I know, I think you have the first affirmatively endorsed acid rain control legislation. And if I am wrong, Montana Power may correct me, but I think you are one of the first in the country and I appreciate that.

Mr. Bartlett.

STATEMENT OF EDWARD F. BARTLETT, LEGAL DEPARTMENT, MONTANA POWER CO.

Mr. BARTLETT. Thank you, Senator, and we thank you for including a western utility viewpoint in today's hearing.

I am Edward F. Bartlett, an attorney of the Montana Power Co. which is an investor-owned electric and gas utility operating in the western two-thirds of Montana. Over 80 percent of the total population of the State live in our service area.

To serve Montana Power's 232,000 electric customers, the company owns and operates 13-hydroelectric facilities and five coal-fired thermal electric plants.

The Montana Power Co. is deeply concerned about acid deposition legislation now being considered by Congress and the potential negative impact of this legislation on ratepayers.

Coal-fired powerplants in Montana and other Western States are already being required to install technological controls at enormous expense. These controls were imposed despite the relatively lower emission levels in the region due to use of low-sulfur fuels and significant use of hydro and nuclear electric generation. Electrical users in the West are already paying for these controls. We can see no equity in proposals to spread the cost of emission reductions beyond the individual source. We oppose a national fee or tax on utilities, consumers, fuel or other proposals that would shift the financial burden from the sources whose emissions are greater and which directly contribute to the acid rain problem.

Under H.R. 3400 our customers and company would pay both for environmental quality in Montana and for reducing emissions in the Midwest. Montana Power customers would pay $7.7 million yearly if the H.R. 3400 proposed one mil user fee were imposed today.

The costs for the air pollution control equipment for Colstrip units 3 and 4 is $500,000,000 which is almost 35 percent of the total generating plant expenditures. We calculate that the cost to customers to cover the fixed charges of these pollution control facilities will represent about 25 percent of the current average retail price our residential customers pay. It is extremely difficult to envision a scenario in which we or our customers would endorse being assessed to pay for someone else to accomplish what we in the West have accomplished without soliciting contributions.

While we advocate that those primarily responsible for the emissions should pay the primary costs, we believe those costs must be fairly and equitably spread throughout all contributing industrial and mobile sources in the affected area. Further, credit should be given for emission improvements already in place and costs of reductions by utilities should and must be fully recoverable in rates.

Montana Power Co. believes that a program aimed at controlling acid deposition must be carefully structured to address the regional nature of the problem. However, any remedial action must be reasonably implemented to insure that control measures produce benefits corresponding to their costs.

To the extent that controls are phased-in corresponding to research results and to the extent that sources are permitted flexibility in achieving emission reductions, the costs can be minimized. Federal requirements should not dictate specific technological means, such as scrubbers, for achieving emission reductions.

Any legislation enacted should also encourage the use of new and innovativve technologies. In this regard, magnetohydrodynamics is one technology which holds out great promise for much cleaner and more efficient burning of coal.

I will conclude my remarks at that point, Senator.

Senator Durenberger. Thank you very much.

Ms. Barratt-Brown, maybe you can start out your statement by describing a "giant step forward" to us, also.

STATEMENT OF ELIZABETH P. BARRETT-BROWN, NATURAL RESOURCES DEFENSE COUNCIL

Ms. Barratt-Brown. I was surprised by that quote. I talked to Steve Dornfeld at length; this question is in regard to an article that appeared this morning in the Minneapolis paper where I commended the Reagan administration for taking a giant step forward. I told Steve that the 21-State control area being considered by the EPA and discussed in my testimony is an unacceptable program. Anything less than 21 States is also unacceptable from our perspective. Unfortunately he did not quote me on this point.

As you have gathered, my name is Elizabeth Barratt-Brown. I am a resource specialist with the Natural Resources Defense Council in Washington, D.C. My testimony reflects the views of the Natural Resources Defense Council and the National Clean Air Coalition, of which the Natural Resources Defense Council is a member.

We believe the time has come to put in place a major emissions control program. Relief must be provided to the areas of our country that have already suffered from acid rain damage and protection afforded to the areas that are vulnerable to future damage.

A full 50-percent reduction in sulfur dioxide emissions is needed to protect sensitive areas, especially in the Eastern States. We call on the Congress to adopt a control program which achieves that 50-percent reduction.

This morning I would like to limit my testimony to three major points. We believe an acid rain control program should have the following characteristics: A 12,000,000-ton reduction target, 50 percent in the eastern United States; a regional or national reduction area no smaller than the 31 States; and no trade-offs of eastern SO_2 emissions for western SO_2 reductions or NO^X reductions because we believe a full 50-percent reduction in sulfur dioxide emissions is needed.

A lot has been said about the problem of acid rain in Minnesota. I will skip over this part of my testimony, and summarize by I will just say that the Upper Midwest, comprised of central and northern Minnesota and Wisconsin and the Michigan highlands, forms an extremely vulnerable area that must be effectively protected in the near term. You recognize the threat to the Upper Midwest; many in the country do not. And I think in the coming months we will see an emphasis from the administration and other groups in Congress to focus on the New England problem and on the Adirondacks of New York. So, I think it's important to stress on the record and for you to voice your concerns about acid rain in Minnesota, Wisconsin, and Michigan.

To protect the natural resources at risk from further degradation, the National Academy of Sciences recommended in 1981 that a 50-percent reduction in acid deposition is necessary. The Academy warned that at current rates of emissions the number of acidified lakes would double by 1990. The recommendation for a 50-percent reduction has since been strengthened by the conclusions of the international scientific experts at the 1982 Stockholm conference on acidification of the environment and from the Canadian scientific experts technical reports released last January under the United States-Canadian Memorandum of Intent.

There has been reference today to the wet sulfate deposition target of 15 to 20 kilograms per hectare per year. Deposition of 15 to 20 kilogram per hectare per year is considered a threshold below which damage occurs. Most of the sensitive areas in the East are receiving deposition well above that level with many areas receiving twice this level. Many scientists argue that a 9 kilograms per hectare per year level is needed to achieve adequate protection against eventual long-term effects. The "tea-cup", or slow draining, lakes of Scandinavia and Minnesota fall within this category, according to the Scandinavian experts.

A 12,000,000 ton or 50-percent reduction target would represent a major step toward saving the thousands of lakes and streams at risk in Minnesota and other areas, and it would provide numerous other important regional benefits. These benefits include lower risks to forests and soils, improved visibility, reduced erosion of buildings and monuments, drinking water supplies, and better protection against human health risks across the Eastern United States, all part of the same problem of sulfate loadings.

The second point, that the reduction be regional or national in scope and cover the 31 Eastern States at a minimum reflects our concern that the reductions achieve an effective measure of resource protection in the near term. Much of the Eastern United States and pockets of the West have resources at risk. Both the Office of Technology Assessment and the EPA have identified sensitive aquatic resources in more than two-thirds of the Eastern 31 States.

I have appended a copy of the EPA national alkalinity map which shows the extent of soils and surface waters in the United States that have low alkalinities and are most likely to be adversely affected by acid rain. This map points out that we are not dealing with a very localized problem, we are dealing with a national problem.

Mr. Uman, from the National Academy of Sciences, remarked that reductions from a large and broad area in the Eastern United States would also result in regional visibility improvement as well as improvement in other air quality problems and also improvement in economically costly materials damage all of which are strongly influenced by acid rain precursors.

Regional reductions are necessary because the atmospheric picture is extremely complex in this region, with many sources contributing to effects in many receptor areas. Because of this phenomenon, and because of conclusions of the recent National Academy of Science's report found that there is a thorough mixing of pollution from sources within a 600-mile radius, and that every source in the Eastern United States should be considered a contributor to the acid rain problem. The idea that sources in 15 or 21 States can be effectively targeted to protect selected receptor areas is therefore flawed. A major finding is that on a regional basis reductions in emissions would lead to directly proportional region-wide reductions in acid deposition. Therefore, if a 50-percent reduction is made in SO_2 emissions in the eastern region of the United States, a region-wide 50-percent reduction in acid deposition will result. The Academy report makes it clear, however, that at present we cannot predict that a 50-percent reduction in 15, 21, or 31 States for that matter, will result in a 50-percent reduction in Minnesota's acid deposition; but what it does tell us is that the larger the region, the greater the probability will be that deposition will be reduced by 50 percent.

Mr. Uman from the National Academy of Sciences stated that he favors a uniform rollback in emissions, an equal percentage from each State. In terms of administering a program, a uniform rollback penalizes States that have cleaned up, and would be significantly more expensive than least cost approach such as the approach, Senator Durenberger, you are interested in. For example, if you cut back emissions by 50 percent in Vermont which emitted in 1980 15,000 tons, I believe, you get a reduction of 7,500 tons. If you cut back by 50 percent in Ohio which emitted close to 3,000,000 tons in 1980, you get a million-and-a-half tons of reductions.

Senator **Durenberger**. And the cost of getting down.

Ms. **Barratt-Brown**. That's right, on a marginal basis it is much more expensive to reduce in Vermont than in Ohio where controls at large sources result in large pollution cutbacks.

We believe that science supports a regional reduction. How reductions occur within the region should be determined on the basis of economic, social, and technical considerations.

The region should not necessarily be limited to the Eastern 31 States. There is reason to be concerned about sources to the west of Minnesota. Recent analysis for EPA indicates the States of North Dakota, Kansas, and Nebraska may, in fact, increase their emissions by 25 percent over the next two decades. There are other States in the West which are indicated on the larger EPA map which I am afraid is not appended to my testimony that indicates that areas in the Cascades, the Sierra Nevadas, the Rocky Mountains, and the Grand Tetons have vulnerable resources, with low-alkalinity lakes and streams. Therefore, an emission control program that goes regionally will better protect resources in the West that are at risk and will also, if you are interested in spreading the cost, spread the costs across the country more evenly. Economic analysis of the Sikorski-Waxman bill, H.R. 3400, indicates that the average cost to the customer would be less than a dollar a month spread across the 48 States. Under a national program scenario, there are arguments in favor of spreading the cost and there are arguments that are equally persuasive that the polluter should pay.

The National Clean Air Coalition has remained neutral in the discussions about a fee on generation or on emissions.

Our major focus is the 50-percent reduction within 10 or 12 years to be achieved on a regionwide basis to protect the extensive resources at risk.

I will now conclude my prepared statement but would be happy to answer questions.

Senator **Durenberger**. Thank you very much for being here today. Final witness is Steve Ring.

STATEMENT OF STEVEN RING, COCHAIRMAN, ACID RAIN TASK FORCE, NORTH STAR CHAPTER, SIERRA CLUB

Mr. **Ring**. I see the crowd is thinning; I will try to be brief.

I am Steven Ring, cochairman of the Acid Rain Task Force of the North Star chapter of the Sierra Club. For the past 5 years we have worked to understand and educate ourselves and the public about acid rain. We have lobbied in support of legislation, participated in public hearings, and held plan conferences about acid rain. I am presently a member of the Minnesota Pollution Control Agency's Technical Review Committee on Acid Rain in which I represent the interests of Minnesota's environmental organization, including the Minnesota Audubon Council, Minnesota Conservation Federation, Minnesota division of the Isaac Walton League, and others.

I appreciate the opportunity to testify on the nature of the acid rain problem in the Upper Midwest, the need for a Federal control program, and the desirable magnitude and scope of such a program. Although I have read most of the technical literature on acid rain, particularly that which applies to this part of the country, I will defer to the scientific panel for an explanation of the technical aspects of the acid rain problem. I do wish, however, to provide and reiterate a few facts about acid rain in this region which I have gleaned from several sources. I will discuss impacts on lakes and streams because they show the first signs of stress from acid rain. I do not mean to minimize, however, the myriad of other documented and possible effects on soils, plants, animals, materials, and human health I will aso confine my remarks mostly to the U.S. side of the border, but the damage and degradation occurs on the Canadian side as well. As a Minnesotan, I am most familiar with this State's resources and most of my remarks apply directly to them. The situation in States to the east, Wisconsin and Michigan, is similar but worse.

Parts of the upper Midwest are just like a patient who feels no symptoms, but whose blood and serum tests indicate the presence of illness Lakes in northeastern Minnesota, northern Wisconsin, and northern Michigan are not yet acidified, but some tests indicate they are undergoing acidification or are likely ot be affected. The illness is present, but obvious symptoms are not yet evident.

Several reports have documented the fact that this region contains the three important ingredients for damage from acid rain to occur: Low pH rainfall, high sulfur deposition, and sensitive areas.

These studies have shown that this region contains lakes which are as sensitive as those in other parts of the world which have sustained damage from acid rain. In northeastern Minnesota alone, 65 percent of the lakes, about 1,000 lakes, are sensitive, that is, they have alkalinities less than 10 miligrams per liter of calcium carbonate. In general, northern Minnesota, northern Wisconsin, and parts of Michigan contain granatic bedrock or soils which have little opportunity to buffer the acid deposited by the rain.

Those acids cause the volume weighted mean pH of rainfall throughout this region to range from about 4.3 in Michigan to 5 in north-central Minnesota. This level of acidity is associated with the beginning of lake acidification in other parts of the world.

Related to rainfall acidity, but perhaps even more important is the total deposition of acid onto a sensitive area. One indicator of this deposition is the amount of sulfate deposited over a particular area per year. We find that the levels of sulfate deposition in Minnesota and Wisconsin are greater than those in the interior of Norway and Sweden where long-term impacts have been documented. Thus there is little reason to believe that the upper Midwest will escape damage from acid rain if the present deposition rates continue.

In fact, some measurements show that degradation may already be occurrring. For instance, the comparison of current and historical alkalinities in Minnesota lakes shows that declines have occurred. The lakes are losing their buffering capacity. Taken separately, each piece of information might be suspect—it might indicate something else happened—but in total it adds to significant cause for concern about the long-term degradation and acidification of these resources. At present, we know of no lakes in Minnesota which have become acid due to acid rain. The good news is, "We have no dead fish;" the bad news is, "We have no dead fish" to strengthen our case for reduction of acid rain deposition in this area. But just as surely as declining fish population in the Adirondacks indicate the final stage of acidification of a lake, these chemical measurements indicate the beginning stages of acidification in the upper Midwest.

If we are to prevent the gradual acidification of these waters and the resultant loss of fish populations as well as other ecosystem damage, we must act now to reduce the amount of acidifying substances falling on them. That means controlling the emission of compounds which form acids in the atmosphere, sulfur dioxide, and the oxides of nitrogen. Of these, the reduction in sulfur dioxide emissions are most important to prevent long-term degradation and damage.

How large should those reductions be? The National Academy of Sciences, the Canadian Government, and several scientists from both Canada and the United States recommend a 50-percent reduction in emission of these compounnds in Eastern North America. With a total nationwide sulfur dioxide production of about 24 million tons in 1980 expected to climb to around 26 million by the year 2000, we support a 10-million-ton reduction in sulfur dioxide emissions with offsets for new growth for a control program of 12,000,000 tons reduction including new growth. Any amount less than that, although helpful, is not consistent with the consensus of most independent scientists who are studying acid precipitation.

The control program must be implemented at the Federal level. Quite simply, wind patterns and the pollutants that go with them do not recognize State or international boundaries. The rain from Hurricane Alicia took less than 2 days to reach the Midwest from Texas; and pollution, whatever there was, came with it. The tremendous mixing capabilities of the atmosphere make it impossible to deal with this problem on a local scale Instead, it must be approached on the scale which the wind patterns operate, a North American continent approach.

To illustrate the problem of local control, consider the Minnesota situation. The State of Minnesota passed an Acid Deposition Control Act in the spring of 1982. Its provisions include the setting of a deposition standard to protect sensitive State resources and the development of a control plan to maintain or achieve compliance with the standard. Instate sources would only be responsible for the portion of deposition in excess of the standard to which they contribute. Current estimates suggest about 30 percent of the deposition in Minnesota comes from instate sources; the rest probably originates in States to the south and west. Although the deposition standard and control plan are not expected to be established until January 1986, it's clear it will be impossible for the State to solve its own acid rain problem.

At this time, there are several acid rain proposals before Congress. Our primary focus in evaluating them is halting and preventing damage to the sensitive ecosystems of North America. To that end we desire at least a 10-million-ton reduction in sulfur dioxide emissions and a minimum of a 31-State control region. Proposals based on some number less than 31 States make the upper Midwest a "national sacrifice area" with respect to acid rain. However, even the 31-State proposal may not adequately protect Minnesota's sensitive areas. Therefore, we would encourage Congress to consider a national control program.

I do not mean to imply by this testimony that there is no genuine scientific uncertainty or controversy about acid rain. But I do want to point out that we have a good general understanding of the process, and considerable scientific evidence and judgment suggest that deposition of acid substances needs to be reduced by about 50 percent. Recent conclusions from our best scientists of the National Academy of Sciences confirm a direct relationship between emissions and deposition. Public opinion polls unanimously confirm the public is willing to pay for clean air and clean water. We stand ready to help you formulate a strong, fair, politically feasible acid rain control bill.

I want to thank you, Senator Durenberger, for bringing these hearings to Minnesota so that the Upper Midwest case could be heard. We appreciate your personal involvement in this important issue as well as your willingness and commitment to take the time to propose legislation calling for large nationwide emission reductions.

If you have any questions, I would be happy to answer them.

Senator **Durenberger**. Thank you, and let me thank all of you. And my regrets, the quickness from which time passes indicates that all of your testimony has been extremely helpful. I think today we have taken another large step forward in coming a little closer to not only recognizing what causes these problems, but some of the factors we are all going to have to take into consideration to resolve. And each time that happens, whether we characterize it as Elizabeth did as a giant step on somebody's part, it probably takes a lot of giant steps because there is a lot of giant actors in this whole process.

So I frankly feel that the hearing was extremely worthwhile, and not just from Minnesota or Upper Midwest perspectives but extremely worthwhile from the national perspective. I am afraid we could not have found the interest on the part of all sides as witnesses or the general interest exhibited by the attendance today if we had held this in most other parts of the United States of America.

So I think it's been very helpful to my colleagues who are not here; but doesn't diminish their interest in the problem, it is just their cognizance of the fact that as long as some people are willing to pick up the ball and roll it, they are all going to look forward to see what happens when it rolls into their court. So I think we have built a good-sized ball here today that we can roll into the court in September and hopefully make some more progress in the control of acid rain.

We may have some more questions and ask you to respond to them in writing which will be part of the record. If anybody else has additional comments that they want made a part of the record of this hearing on any point that was made by any of the witnesses, it would be helpful to the committee to have you do that within the next couple of weeks.

So with that, the hearing is adjourned.

[Whereupon the hearing was adjourned to reconvene at the call of the Chair.]

[Statements supplied for the record follow:]

Testimony of

SANDRA S. GARDEBRING
Executive Director
MINNESOTA POLLUTION CONTROL AGENCY

before the

SENATE ENVIRONMENT AND PUBLIC WORKS COMMITTEE
HEARING ON ACID RAIN

August 25, 1983

Good Morning Mr. Chairman and Senators, I want to thank you for this opportunity to provide the committee with the Minnesota Pollution Control Agency's (MPCA) views and concerns regarding acid deposition control legislation. The MPCA has commented on this important legislation several times in the past year through Senator Durenberger's office. The Senator and his staff have been very helpful in forwarding our comments to the Committee, and for this I thank you, Senator. Also, the committee members, particularly Senator Stafford, and the committee staff have given our comments and concerns serious consideration, and for that I also thank you.

As you know, acid deposition is of great concern to Minnesotans. Due to the glacial and geologic history of Minnesota, much of northern and eastern Minnesota is sensitive to acid deposition. As the glaciers passed back and forth over Minnesota, they left thousands of lakes. But the glaciers, through their scouring action, also left very thin soils and exposed bedrock, both of which have low capacities to neutralize acid deposition.

Our studies here at the MPCA and the Department of Natural Resources, as well as those at the EPA lab in Duluth, have resulted in a data base that is second to none. We have learned from our studies that about 3,500,000 acres of forest soils in Minnesota are sensitive or potentially sensitive to acid deposition. That represents about 19% of the forested land in Minnesota.

Although Minnesota is known as the land of 10,000 lakes, we really have more than 12,000 lakes larger than 10 acres. Of those, we believe that between 1,500 and 2,500 lakes in Minnesota are sensitive to acid deposition. That represents about 25% of the lakes in the state that are classified as fishing lakes.

In addition to our concerns about lakes and forests, we estimate that 1,200,000 acres of peatlands in Minnesota may be affected by acid deposition. Some of these sensitive peatlands represent a unique wilderness of wildlife and vegetation that cannot be found in any other state outside of Alaska.

Altogether, we estimate that about 15% or almost 8,000,000 acres of Minnesota's forests, peatlands, and watersheds are sensitive to acid deposition. The attachment to my testimony is a map of the sensitive and potentially sensitive areas in Minnesota. These areas cover much of eastern and northeastern Minnesota and include Voyaguers National Park, the Superior National Forest, the 1,000,000 acre Boundary Waters Canoe Area Wilderness (BWCA) and even include some park and forested areas in the Twin Cities.

Agriculture, tourism, and forestry are the three largest industries in Minnesota. Two of these industries, tourism and forestry, are seriously threatened by acid rain. Agriculture, though not currently threatened, could be affected if rainfall becomes more acidic in the future. One study shows that the first signs of lake acidification in the BWCA could result in an annual loss of about $40,000,000 per year and 3,000 jobs. That represents only a fraction of the total tourism and sport fishing industry in Minnesota. We are proud of our beautiful environment in Minnesota, the many lakes, the forest, Voyaguers National Park, and the Boundary Waters Canoe Area Wilderness. So acid deposition is an economic, environmental, and emotional issue to our state.

The rainfall in Minnesota ranges from well-buffered rain in western and southwestern Minnesota to highly acidic rain with pH's in the low 4.0's in extreme northeastern part of the state. Unfortunately, the rain is most acidic in the areas that are most sensitive. So far, we have found no dead lakes in Minnesota. However, the acidity of precipitation and the rates of deposition in northeastern Minnesota is already great enough to begin causing subtle chemical changes in our most sensitive resources. Computer modelling shows that about 30% of the acid deposition falling in Minnesota comes from sources within the state. Another 20% or so comes from Canadian sources, primarily smelters in Ontario and Manitoba. The remaining 50% comes from other states. The other states contributing to acid deposition in Minnesota include our neighboring states to the west, east, and the south. Missouri and western Illinois are likely the largest out-of-state contributors.

We have recognized that our own emissions contribute significantly to acid deposition in our own state. As a result of environmental concerns and the responsible action of industry, emissions of sulfur dioxide in Minnesota are much lower today than ten years ago. We intend to reduce emissions even further. In 1982, the state legislature passed a bill known as the Minnesota Acid Deposition Control Act. This establishes Minnesota as the first state to begin regulating acid deposition. As a result of that Act, we have developed a formal inventory of sensitive resources. We are now in the process of developing a formal acid deposition standard to protect those resources. By January 1, 1986, we will have developed a control plan to meet the standard, and our sources must be in compliance by 1990.

Even though the Acid Deposition Control Act sets a rigid schedule for reductions by establishing a 1990 compliance date, we have already begun reducing emissions. Northern States Power Company (NSP) at our request, has agreed to reduce emissions at three of its existing power plants in order to offset emission growth that is likely to result from the construction and operation of a new coal-fired power plant which is currently under construction. This action demonstrates how we can reduce emissions and accomodate future growth.

As far as federal action is concerned, we have been frustrated with the sluggish reactions of Congress and the federal government. One example of that frustration is the Acid

Deposition Control Act. Another example is our Memorandum of Understanding with Ontario to Combat Acid Deposition, which I recently signed on behalf of the State of Minnesota. I have included a copy of that Memorandum with my testimony.

The MPCA has been reviewing potential legislative proposals for a national acid rain control program for over two years. We are naturally concerned that any federal legislation address acid deposition in such a manner that will ensure adequate protection for Minnesota's sensitive resources. The steps necessary to control acid deposition in Minnesota are similar but at the same time, geographically different than those necessary to control acid deposition in New England and New York. This is because the sources that contribute the most to acid deposition in Minnesota are different than the sources that contribute the most to deposition in New England. Different sources contribute to acid deposition in the Western states and in the Southeastern states as well. The following concepts that I will present strive to address the geography of acid deposition equitably.

First, an interim freeze or cap on total U. S. emissions of sulfur dioxide from major sources (sources greater than 100 tons/year) should be initiated to ensure that emissions of sulfur dioxide do not increase until a federal control plan or legislation is enacted. This action is needed to prevent exacerbation of the acid deposition problem in areas that are already being affected. Such a cap could be applied on a state-wide basis to allow the state flexibility in accomodating future growth in a manner that best suits the state.

Second, again to help accomodate future growth, all major new sources should be required to employ the "Best Available Control Technology", which is an existing requirement of the Clean Air Act.

Third, we believe that current research indicates sulfur dioxide is the pollutant that is primarily responsible for long-term acidification of the environment in much of the United States. Because more is understood about the effects of sulfur dioxide on the environment, legislation should be primarily addressed to sulfur dioxide at this time. However, we recognize the concerns about other pollutants' contributions to the problem and believe that legislation should not exclude control of other pollutants, particularly as more is learned about their contributions.

Fourth, we think that all states should be included in federal acid deposition control legislation. Acid deposition is not just an eastern U. S. problem. Sensitive resources exist in the Northeast, the Southeast, the Upper Midwest, and throughout the mountains of the West. Unfortunately, rainfall is acidic in many of these areas. Sources of sulfur dioxide and acid deposition exist in every state. Therefore, every state should have protection from acid deposition and every states' sources of acid deposition should be considered for control. A bill that is drafted solely to reduce acid deposition in New England may not significantly reduce acid deposition in the Upper Midwest.

Fifth, to adequately protect sensitive resources in the United States and Canada, we believe a reduction in sulfur dioxide emissions on the order of 50% is warranted. This represents a reduction of 10,000,000 to 12,000,000 tons/year in the United States. Emission reductions can be allocated in a number of ways. The method of allocation should take into consideration existing emission levels and emission rates, so as to credit states that already employ emission controls.

Sixth, we believe that strengthening language must be added to the existing provisions for interstate transport of pollutants in the Clean Air Act. The current interstate transport provisions do not recognize acid deposition as a form of pollution. Sections 110 and 126 must be strengthened to ensure that one state is prevented from emitting air pollution which could endanger public health or welfare in another state, regardless of violations of ambient standards. Modification of these sections of the Act becomes even more important if legislation is not applied to all states. This is a subject that the MPCA has commented on in the past and such language was included in the committee's 1982 version.

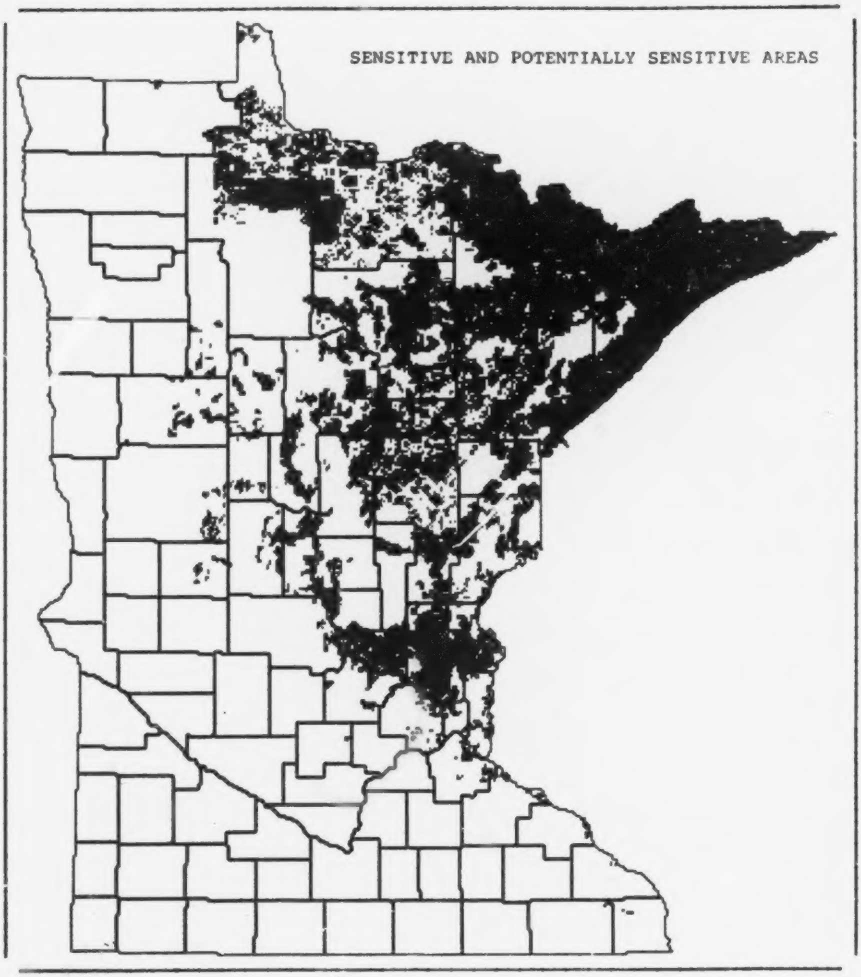
Finally, I would like to comment on the concept of a funding mechanism for the purpose of assisting in mitigating the costs of complying with a control act. I have discussed this issue with the Minnesota Department of Energy and Economic Development and the Department of Public Services. My following comments regarding a funding mechanism reflect our unanimous opinions about this subject. Most current federal legislation that controls air and water pollution revolves around the concept that the polluter should bear the cost of pollution control. Ideally that concept should work for acid deposition as well. Therefore, we prefer no funding mechanism for acid deposition control.

However, we also recognize the necessity of developing legislation that is politically acceptable to Congress in order to achieve our goal of mitigating acid deposition in a timely manner. A funding mechanism may indeed be necessary in order to meet that goal. If some type of a funding mechanism is to be added, we prefer one that recognizes the existing degree of pollution control in a state. An emissions based funding source such as a sulfur dioxide emissions tax would meet that requirement. The kilowatt hour fee, or generation tax as it is sometimes called, does not appear to take into account sulfur dioxide reductions, which have already taken place in states like Minnesota and therefore, places an inequitable burden on the rate payers and tax payers of Minnesota. Until specifics have been announced regarding the levels of various tax proposals, we will not know the exact costs to Minnesota for controlling acid deposition and for contributing to a "fund ". However, under either an emission tax or a generation tax, the costs to the average citizen are likely to be more than offset by the benefits of stopping acid deposition.

I have a skillful staff that is well-educated in the various scientific and political issues involving acid deposition. In addition, we have the computer modelling capabilities necessary to determine the benefits of any sulfur dioxide emission reduction scenario that may be proposed. We stand ready to assist the committee staff in assessing any issues that may develop related to this important legislation. Also my staff, along with the State Departments of Public Services and Energy and Economic Development will assess the costs to Minnesotans for any of the proposed reduction scenarios or funding mechanism.

Again, I thank you for this opportunity to discuss this important issue and I wish you well in your efforts to pass legislation in Congress.

ATTACHMENT



SENSITIVE AND POTENTIALLY SENSITIVE AREAS

MEMORANDUM OF UNDERSTANDING

ON

CO-OPERATION IN COMBATTING

ACIDIFICATION OF THE ENVIRONMENT

BETWEEN

THE PROVINCE OF ONTARIO

AND

THE STATE OF MINNESOTA

5th of August, 1983

MEMORANDUM OF UNDERSTANDING

on co-operation in combatting acidification of the environment

BETWEEN

THE PROVINCE OF ONTARIO, represented for the purposes of this Memorandum of Understanding by Andrew S. Brandt, Minister of the Environment, and Thomas L. Wells, Minister of Intergovernmental Affairs, and hereafter designated as "Ontario",

AND

THE STATE OF MINNESOTA, represented for the purposes of this Memorandum of Understanding by Sandra S. Gardebring, Executive Director of the Pollution Control Agency, and hereafter designated as "Minnesota".

SINCE Ontario and Minnesota share a deep concern about the present and future effects of transboundary air pollution, and in particular the serious and urgent problem of acid deposition;

SINCE the unique ecosystems of their respective adjacent territories are highly susceptible to the effects of acid deposition;

SINCE they share a common resolve to reduce and prevent transboundary air pollution in a cost-effective way and limit the damage it causes;

SINCE they are convinced that the best means to protect the environment from the effects of acid deposition is through the achievement of reductions in emissions of the pollutants that are its cause;

SINCE a significant amount of the acid deposition they receive has a common source and originates with emitters situated outside their respective territories;

SINCE they share a common resolve to improve the scientific understanding of the source, magnitude, and consequences of the problems of acid deposition;

SINCE they acknowledge the importance of mutual cooperation and collaboration to address this common problem;

THEREFORE: the Province of Ontario and the State of Minnesota agree on the following:

...2

The purpose of this Memorandum is to ensure close cooperation and collaboration in the efforts of Ontario and Minnesota to improve the understanding of both the possible effects of acid deposition on their territories, and the steps necessary to reduce and prevent it.

To accomplish this goal, they agree to share scientific data and technical expertise, to collaborate on efforts to develop a better understanding of the causes and effects of acid deposition, and to collaborate on the establishment of integrated national action plans to reduce and prevent emissions, in a cost-effective manner, of the pollutants that are its cause.

SECTION 2: MUTUAL OBLIGATIONS OF THE PARTIES

2.1 Exchange of Information

The parties agree to provide, in a timely manner and when requested, data from acid deposition monitoring stations and related lakes studies, and any other requested information relating to the subject of acid deposition.

2.2 Emission Inventories

The parties agree to provide emission inventories of pollutants related to acid deposition from sources within their territories and to assist in obtaining emission inventories from other jurisdictions within their respective countries. Both parties will also provide projected future emissions when available.

2.3 Technical Expertise

Both parties agree to share technical expertise on subjects related to acid deposition. Such expertise may take the form of scientific review of work in progress and advice on future studies.

2.4 Joint Studies

The parties agree to work cooperatively on joint studies including but not limited to: i) the application of existing long-range transport and economic models for the purpose of developing regulatory strategies; ii) the development and application of an Acid Deposition and Oxidants Model for the purpose of developing regulatory strategies: iii) the refinements to dose/response data and models for the purpose of application to susceptible ecosystems in Ontario and Minnesota; iv) research studies to better understand the relationship between acid loadings and ecosystem response and the benefits provided by reducing acid loadings in affected regions.

SECTION 3: ABATEMENT STRATEGIES

3.1 National Strategies

The parties agree to work cooperatively in developing cost-effective national strategies to reduce and prevent the impacts of acid deposition. Such cooperation shall include identification of source regions and the development of emission reduction strategies, as required in 2.4 i), including an analysis of their socio-economic impacts, as well as encouragement and support on the national level to ensure the adoption of national strategies.

3.2 Alternative Strategies

In the absence of national action, the parties agree to collaborate on the development of alternative strategies that result in reductions in emissions of acid forming pollutants, attainable within existing legal and legislative framework.

SECTION 4: EFFECTIVE DATE

This Memorandum of Understanding will come into effect upon its signature by both parties, and will remain in effect until terminated upon six months notice given in writing by one of the parties to the other.

And the parties' duly authorized representatives have signed.

Signed on behalf of

THE PROVINCE OF ONTARIO

by

Andrew S. Brandt
Minister of the Environment.

date: August 5, 1983

by Thomas L. Wells

Thomas L. Wells
Minister of Intergovernmental Affairs.

date:

THE STATE OF MINNESOTA

by Sandra S Gardebring

Sandra S. Gardebring
Executive Director
Minnesota Pollution
Control Agency.

date: August 5, 1983

H.F. No. 1789
CHAPTER No.
482

AN ACT

relating to the environment; limiting and reducing emissions of sulphur dioxide in the state; requiring adoption of an acid deposition control standard and plan by the pollution control agency; requiring reports; imposing an assessment on utilities; appropriating money; amending Minnesota Statutes 1981 Supplement, Section 116C.69, Subdivision 3; proposing new law coded in Minnesota Statutes, Chapter 116.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF MINNESOTA:

Section 1. [116.42] [LEGISLATIVE INTENT.]

The legislature recognizes that acid deposition substantially resulting from the conduct of commercial and industrial operations, both within and without the state, poses a present and severe danger to the delicate balance of ecological systems within the state, and that the failure to act promptly and decisively to mitigate or eliminate this danger will soon result in untold and irreparable damage to the agricultural, water, forest, fish, and wildlife resources of the state. It is therefore the intent of the legislature in enacting sections 1 to 4 to mitigate or eliminate the acid deposition problem by curbing sources of acid deposition within the state and to support and encourage other states, the federal government, and the province of Ontario in recognizing the dangers of acid deposition and taking steps to mitigate or eliminate it within their own jurisdictions.

Sec. 2. [116.43] [ACID DEPOSITION DEFINED.]

As used in sections 1 to 4, "acid deposition" means the wet or dry deposition from the atmosphere of chemical compounds, usually in the form of rain or snow, having the potential to form an aqueous compound with a pH level lower than the level considered normal under natural conditions, or lower than 5.6.

Sec. 3. [116.44] [SENSITIVE AREAS; STANDARDS.]

Subdivision 1. [LIST OF AREAS.] By January 1, 1983, the pollution control agency shall publish a preliminary list of counties determined to contain natural resources sensitive to the impacts of acid deposition. Sensitive areas shall be designated on the basis of:

(a) the presence of plants and animal species which are sensitive to acid deposition;

(b) geological information identifying those areas which have insoluble bedrock which is incapable of adequately neutralizing acid deposition; and

(c) existing acid deposition reports and data prepared by the pollution control agency and the federal environmental protection agency. The pollution control agency shall conduct public meetings on the preliminary list of acid deposition sensitive areas. Meetings shall be concluded by March 1, 1983, and a final list published by May 1, 1983. The list shall not be subject to the rulemaking or contested case provisions of chapter 15.

Subd. 2. [STANDARDS.] (a) By January 1, 1985, the agency shall adopt an acid deposition standard for wet plus dry acid deposition in the acid deposition sensitive areas listed pursuant to subdivision 1.

(b) By January 1, 1986, the agency shall adopt an acid deposition control plan to attain and maintain the acid deposition standard adopted under clause (a), addressing sources both inside and outside of the state which emit more than 100 tons of sulphur dioxide per year. The plan shall include an analysis of the estimated compliance costs for facilities emitting sulphur dioxide. Any emission reductions required inside of the state shall be based on the contribution of sources inside of the state to acid deposition in excess of the standard.

(c) By January 1, 1990, sources located inside the state shall be in compliance with the provisions of the acid deposition control plan.

Sec. 4. [116.45] [REPORTS TO THE LEGISLATURE.]

By January 1, 1986, the agency shall submit its acid deposition control plan to the appropriate substantive committees of both houses of the legislature. By January 1, 1987, and each two years thereafter until January 1, 1991, the agency shall submit to the legislative committees a report detailing the reduction of sulphur dioxide needed to meet the requirements of section 3 and the progress which has been made to meet those requirements.

Sec. 5. Minnesota Statutes 1981 Supplement, Section 116C.69, Subdivision 3, is amended to read:

Subd. 3. [FUNDING; ASSESSMENT.] The board shall finance its base line studies, general environmental studies, development of criteria, inventory preparation, monitoring of conditions placed on site certificates and construction permits, and all other work, other than specific site and route designation, from an assessment made quarterly, at least 30 days before the start of each quarter, by the board against all utilities. The assessment shall also include an amount sufficient to cover 60 percent of the costs to the pollution control agency of developing the acid deposition control plan required by sections 1 to 4; this amount shall be certified to the board by the executive director of the pollution control agency. Each share shall be determined as follows: (1) the ratio that the annual retail kilowatt-hour sales in the state of each utility bears to the annual total retail kilowatt-hour sales in the state of all such utilities, multiplied by 0.667, plus (2) the ratio that the annual gross revenue from retail kilowatt-hour sales in the state of each utility bears to the annual total gross revenues from retail kilowatt-hour sales in the state of all such utilities, multiplied by 0.333, as determined by the board. The assessment shall be credited to the general fund and shall be paid to the state treasury within 30 days after receipt of the bill, which shall constitute notice of said assessment and demand of payment thereof. The total amount which may be assessed to the several utilities under authority of this subdivision shall not exceed the sum of the annual budget of the board for carrying out the purposes of this subdivision plus 60 percent of the annual budget of the pollution control agency for developing the plan required by sections 1 to 4. The assessment for the second quarter of each fiscal year shall be adjusted to compensate for the amount by which actual expenditures by the board and the pollution control agency for the preceding fiscal year were more or less than the estimated expenditures previously assessed.

Sec. 6. [APPROPRIATION.]

The sum of $81,455 is appropriated from the general fund to the agency for the purposes of this act; for fiscal year 1983, the assessment pursuant to section 5 shall not exceed this amount.

Sec. 7. [EFFECTIVE DATE.]

Section 5 is effective June 1, 1982. Sections 1 to 4 are effective July 1, 1982.

H. F. No. 1789

Harry A. Sieben, Jr.
Speaker of the House of Representatives.

Jack Davies

Jack Davies
President of the Senate.

Passed the House of Representatives this 9th day of March in the year of Our Lord one thousand nine hundred and eighty-two.

Edward A Burdick

Edward A. Burdick
Chief Clerk, House of Representatives.

Passed the Senate this 12th day of March in the year of Our Lord one thousand nine hundred and eighty-two.

Patrick E. Flahaven

Patrick E. Flahaven
Secretary of the Senate.

Approved

3/11/82

Albert H. Quie
Governor of the State of Minnesota.

Filed

March 19, 1982

Joan Anderson Growe

Joan Anderson Growe
Secretary of State.

PRESENTATION BY THE PROVINCE OF ONTARIO TO A HEARING OF THE U.S. SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

TESTIMONY BEFORE
SENATOR DURENBERGER

ROSEVILLE, MINNESOTA

AUGUST 25, 1983

ONTARIO IS EXTREMELY PLEASED TO BE REPRESENTED HERE TODAY AND TO HAVE THE OPPORTUNITY TO PRESENT ITS POSITION ON THE ISSUE OF ACID RAIN AND THE NEED FOR IMMEDIATE CANADA/U.S. ACTION TO REDUCE ACID RAIN PRECURSORS.

AQUATIC SYSTEMS: SENSITIVE AREAS AND DOCUMENTED EFFECTS

SENSITIVE AQUATIC SYSTEMS WHICH RECEIVE ACID, BOTH DIRECTLY AND INDIRECTLY FROM PRECIPITATION, CAN SUFFER CHEMICAL AND BIOLOGICAL DAMAGE. SINCE THERE ARE OVER ONE QUARTER OF A MILLION LAKES IN THE PROVINCE OF ONTARIO, ACID RAIN IS A CRITICAL ENVIRONMENTAL ISSUE HERE.

ACIDS FALLING ON THE EARTH'S SURFACE MAY BE NEUTRALIZED BY CHEMICAL REACTION WITH BASIC MATERIALS IN THE SOIL AND WATER. AREAS UNDERLAIN BY ROCK CONTAINING LARGE AMOUNTS OF BASIC MATERIAL (SUCH AS LIMESTONE) CAN NEUTRALIZE THE ACIDS FOR INDEFINITE PERIODS OF TIME WITH ONLY MINOR CHANGES IN THE CHEMICAL COMPOSITION OF THE RUNOFF. IF, HOWEVER, THE SOILS AND BEDROCK HAVE LITTLE CAPACITY TO NEUTRALIZE THE ACID (FOR EXAMPLE, THE SPARINGLY SOLUBLE ROCKS OF THE PRECAMBRIAN SHIELD), THE ACID LOADING CAN EXCEED THE NEUTRALIZING CAPACITY AND RUNOFF WATER WILL BE ACIDIC WITH CONSEQUENTIAL BIOLOGICAL DAMAGE IN STREAMS AND LAKES.

THE ALKALINITY OF LAKE AND RIVER WATER IS A CHEMICAL MEASURE OF ITS CAPACITY TO NEUTRALIZE ACID AND IS COMMONLY REFERRED TO AS THE BUFFERING CAPACITY. THE GREATER THE ALKALINITY, THE GREATER THE CAPACITY TO NEUTRALIZE ACID. LAKES IN AREAS

OF CALCAREOUS (LIMESTONE) SOILS HAVE HIGH ALKALINITIES AND pH VALUES GENERALLY ABOVE 7.0. BY CONTRAST, UNPOLLUTED LAKES LOCATED IN HARD ROCK GEOLOGICAL CONDITIONS (SUCH AS THE PRECAMBRIAN SHIELD AREA OF ONTARIO) HAVE LOW ALKALINITIES AND pH VALUES GENERALLY IN THE RANGE OF 6.0 TO 7.0. WHILE THESE LAKES ARE ON THE ACIDIC SIDE OF pH 7.0, THEY STILL HAVE HEALTHY AQUATIC LIFE.

LAKES WITH LOW ALKALINITY ARE REGARDED AS SENSITIVE TO THE EFFECTS OF ACIDIC RAIN SINCE THEY HAVE A LOW CAPACITY TO MAINTAIN (OR BUFFER) THE pH AT ACCEPTABLE VALUES WHEN EXCESSIVE ACID IS ADDED FROM THE ATMOSPHERE.

THE MEMORANDUM OF INTENT WORK GROUP 1 ON IMPACT ASSESSMENT IN ITS FINAL REPORT ESTIMATED THAT 36% (10,848 KM^2) OF SURFACE WATER IN ONTARIO IS IN A MODERATE OR HIGH DEPOSITION AREA COMBINED WITH A LOW OR MODERATE POTENTIAL TO REDUCE ACIDITY.

OVER TIME, THE ACID LOADING CAN VIRTUALLY EXHAUST THE NEUTRALIZING (OR BUFFERING) CAPACITY OF THE SOILS IN SENSITIVE AREAS AND THE RUNOFF CAN BECOME NEARLY AS ACIDIC AS THE RAINFALL ITSELF. WHEN THE ALKALINITY OF STREAMS AND LAKES FALLS TO ZERO (pH 4.5-5.0), THE WATERBODY IS CALLED "ACIDIFIED". AT THESE pH LEVELS, FISH POPULATIONS ARE SEVERELY STRESSED AND WILL EVENTUALLY BE LOST.

THEREFORE, THE ULTIMATE RESULT OF DEPOSITION OF ACIDS IN SENSITIVE AREAS IS ACIDIFICATION OF THE SURFACE WATER WITH LOSS OF FISH POPULATIONS AND CONCOMITANT DAMAGE TO OTHER AQUATIC LIFE FORMS.

THE CURRENT ACID LOADINGS TO PARTS OF THE PRECAMBRIAN ROCK AREAS OF ONTARIO, AND IN PARTICULAR, THE IMPORTANT RECREATIONAL AREAS OF MUSKOKA AND HALIBURTON, ARE CAUSING SOME LAKES AND RIVERS TO HAVE LOW pH VALUES FOR A FEW WEEKS DURING SPRING MELT AND FOR SEVERAL HOURS OR DAYS DURING HEAVY SUMMER AND AUTUMN RAINS. THESE LAKES ARE REGARDED AS ACID-STRESSED. ALUMINUM LEVELS IN SOME STUDY STREAMS ARE IN THE RANGE OF VALUES KNOWN TO BE LETHAL TO FISH FROM LABORATORY STUDIES.

IN ORDER TO ASCERTAIN THE GEOGRAPHICAL BREADTH OF THE PROBLEM, AN EXTENSIVE SURVEY OF LAKES IN THE PROVINCE WAS INITIATED IN 1979. LAKE ALKALINITY VALUES HAVE BEEN MEASURED ON SOME 4,016 LAKES IN VARIOUS AREAS OF THE PRECAMBRIAN SHIELD. OUT OF THE 4,016 LAKES SURVEYED TO DATE, 155 LAKES OR 3.9% WERE FOUND TO BE ACIDIFIED TO THE EXTENT THAT THEIR ABILITY TO SUPPORT AQUATIC LIFE IS EXTREMELY LIMITED. A TOTAL OF 2,896 LAKES, ACCOUNTING FOR 72.2% OF THOSE SURVEYED, WERE FOUND TO HAVE SOME SUSCEPTIBILITY TO ACIDIFICATION (13% WERE EXTREMELY SENSITIVE, 41.1% WERE MODERATELY SENSITIVE AND 18.1% WERE OF LOW SENSITIVITY). TWENTY-FOUR PERCENT (965 LAKES) WERE FOUND TO BE NOT SENSITIVE TO THE CUMULATIVE EFFECTS OF ACID RAIN.

THE NUMBER OF LAKES SAMPLED IN EACH AREA TO DATE IS SMALL IN COMPARISON TO THE TOTAL LAKES IN THESE AREAS, BUT BASED ON THIS DATA, IT IS BECOMING CLEAR THAT A HIGH PERCENTAGE OF THE LAKES IN THE ENTIRE PRECAMBRIAN SHIELD FALL IN THE EXTREMELY OR MODERATELY SENSITIVE CATEGORIES.

THE LAKES IN THE EXTREME SENSITIVITY CATEGORY ARE CURRENTLY ACID STRESSED AND ARE LIKELY TO BE ACIDIFIED BY LONG RANGE TRANSPORT IF CURRENT ACID LOADINGS CONTINUE. LOSS OF BUFFERING CAPACITY IS CUMULATIVE, ITS RATE AND TIMING DEPENDENT ON THE RATE OF DEPOSITION. ONCE LOST, THERE IS NOTHING TO PREVENT THE LAKE FROM QUICKLY ACIDIFYING.

ON A SHORT-TERM OR EPISODIC BASIS, DETRIMENTAL WATER QUALITY EFFECTS ARE BEING OBSERVED NOW. IN THE MUSKOKA-HALIBURTON AREA OF ONTARIO WHICH IS BEING INTENSIVELY STUDIED, ACIDS (HYDROGEN IONS) FROM ATMOSPHERIC DEPOSITION ARE NEUTRALIZED DURING MOST OF THE YEAR.

HOWEVER, THE HYDROGEN IONS STORED IN THE SNOWPACK ENTER STREAMS AND LAKES IN THE SPRING THAW AND MOST OF THE TOTAL ANNUAL ACID INPUT OCCURS DURING THE SPRING MELT. THE LARGE VOLUME OF WATER, COUPLED WITH LESS CHANCE FOR INTERACTION WITH THE FROZEN SOILS, RESULTS IN "SHOCK" LOADINGS OF ACID TO STREAMS AND THE SURFACE WATERS OF LAKES.

IN ADDITION TO DIRECT EFFECTS ON SURFACE WATER pH, ACIDIC PRECIPITATION HAS THE POTENTIAL OF INCREASING THE LEACHING

RATE OF MATERIAL FROM THE WATERSHED. ALUMINUM IS A MAJOR CONSTITUENT OF THE BEDROCK MATERIAL IN THE PRECAMBRIAN AREA AND IT TENDS TO BE DISSOLVED BY ACIDIC RUNOFF.

IT APPEARS THAT THE pH AND ALUMINUM CONCENTRATIONS BEING OBSERVED IN THE DORSET LAKES DURING SPRING SNOW MELT FALL WITHIN THE RANGES WHICH LABORATORY EXPERIMENTS HAVE SHOWN TO BE LETHAL TO FISH.

INTENSIVE STUDIES ON THE BIOLOGICAL EFFECTS OF OBSERVED WATER QUALITY CHANGES ARE BEING CARRIED OUT IN A SMALL NUMBER OF LAKES. FISH KILLS HAVE BEEN OBSERVED IN ONE LAKE. COMPLETE LOSS OF FISH POPULATIONS CONCOMITANT WITH LAKE ACIDIFICATION ARE KNOWN FOR SEVERAL LAKES, THE MECHANISM BEING RECRUITMENT FAILURE. THE LOSS OF OLDER FISH IN THE POPULATION IS OBSERVED IN ACID-STRESSED CROSSON LAKE.

MERCURY CONCENTRATIONS ARE ELEVATED IN FISH FROM LAKES WITH pH VALUES BELOW ABOUT 6.0. THERE IS REASON TO SUSPECT THAT INCREASED MAN-MADE ATMOSPHERIC EMISSIONS OF MERCURY FROM COAL BURNING, COUPLED WITH ACIDIFICATION OF PRECIPITATION AND SURFACE WATERS, WILL LEAD TO HIGHER MERCURY CONCENTRATIONS IN FISH AND TO MORE LAKES BEING AFFECTED.

ANY LOSS OR MODIFICATION OF THE QUALITY OF SPORT FISH IS A MAJOR CONCERN TO THE SPORT FISHING INDUSTRY VALUED AT HUNDREDS OF MILLIONS OF DOLLARS PER YEAR IN ONTARIO.

THE POTENTIAL FOR OTHER BIOLOGICAL EFFECTS HAS ALSO BEEN SHOWN AND IN MANY CASES DAMAGE HAS BEEN DOCUMENTED BY FIELD OBSERVATIONS. OBSERVED EFFECTS ON BIOTA IN ACIDIFIED SYSTEMS INCLUDE A DECLINE IN THE BREEDING POPULATION OF CERTAIN AMPHIBIANS, REDUCED NUMBERS OF ZOOPLANKTON AND BENTHIC MACROINVERTEBRATES, CHANGES IN ALGAL COMMUNITIES, THE OCCURRENCE OF A FOUL SMELLING ALGA THAT RESTRICTS RECREATIONAL USE OF THE LAKE AND DECREASED MICROBIAL DECOMPOSITION RATES WITH POTENTIAL EFFECTS IN LAKE TROPHIC STATUS.

THE ACID STRESSED LAKES UNDER STUDY ARE SHOWING MANY INSTANCES OF BIOLOGICAL DAMAGE. IT IS HIGHLY LIKELY THAT SIMILAR DAMAGE IS OCCURRING IN THE THOUSANDS OF SIMILARLY ACID-STRESSED LAKES IN ONTARIO.

THE MUSKOKA-HALIBURTON AREA IS ONE OF THE HEAVIEST LOADED AREAS IN THE PROVINCE, EXPERIENCING AN ACID LOADING OF FROM 23 TO 29 KG SULPHATE/HA·YR WET AND 31 TO 42 KG SULPHATE/HA·YR BULK. THE CANADIAN MEMBERS OF THE MEMORANDUM OF INTENT WORK GROUP 1 ON IMPACT ASSESSMENT RECOMMENDED A TARGET LOADING OF 20 KG/HA·YR WET SULPHATE TO PROTECT ALL BUT THE MOST SENSITIVE SURFACE WATERS. ONTARIO SCIENTISTS PROVIDED VALUABLE INPUT TO THE WORK GROUP'S FINAL REPORT AND THE PROVINCE OF ONTARIO AGREES WITH THE FINDINGS OF THIS REPORT.

TERRESTRIAL SYSTEMS: POTENTIAL EFFECTS

ACIDIC PRECIPITATION HAS THE POTENTIAL TO CAUSE SERIOUS AND WIDESPREAD EFFECTS ON TERRESTRIAL ECOSYSTEMS IN CERTAIN AREAS OF THE WORLD. THESE AREAS INCLUDE EASTERN CANADA, NORTHEASTERN U.S.A., AND SOUTHERN SWEDEN AND NORWAY.

IN EXPERIMENTS USING SIMULATED ACIDIC PRECIPITATION, A NUMBER OF ADVERSE EFFECTS HAVE BEEN PRODUCED IN SOILS AND VEGETATION.

WITH VEGETATION, A PARADOX SOMETIMES OCCURS, IN THAT THE NITROGENOUS PORTION OF ACIDIC PRECIPITATION CAN ACT AS A FERTILIZER AND STIMULATE PLANT GROWTH.

IT SHOULD BE UNDERSTOOD THAT THE EXPERIMENTAL RESULTS OBTAINED SO FAR ARE NOT DIRECT PROOF THAT SIGNIFICANT TERRESTRIAL EFFECTS ARE OCCURRING IN NATURE UNDER THE INFLUENCE OF CURRENTLY MEASURED INPUTS OF ACIDIC SUBSTANCES IN PRECIPITATION. HOWEVER, ALTHOUGH THE ACIDIC CONCENTRATIONS OF SOLUTIONS USED IN EXPERIMENTS HAVE USUALLY BEEN MORE ACIDIC THAN THOSE MEASURED IN NORMALLY OCCURRING PRECIPITATION, THERE IS SOME EXPERIMENTAL EVIDENCE THAT FOLIAR INJURY CAN OCCUR AT A pH OF 4.0, AN ACIDITY LEVEL WHICH HAS BEEN EXCEEDED DURING SOME RAINFALL EVENTS IN ONTARIO.

IN AGRICULTURAL AREAS, EFFECTS ON SOIL ARE NOT THOUGHT TO POSE A GREAT THREAT BECAUSE OF ADDITIONS OF LIME AND FERTILIZER IN THE PRACTICE OF CROP MANAGEMENT.

WITH RESPECT TO FOREST PRODUCTIVITY, IT IS POSSIBLE THAT EXCESSIVE LEACHING OF NUTRIENTS FROM THE SOIL WILL RESULT IN IMPOVERISHED TREE GROWTH. REDUCTIONS IN FOREST GROWTH HAVE BEEN REPORTED IN CERTAIN PARTS OF SOUTHERN SWEDEN AND WEST GERMANY, BUT IT IS DIFFICULT TO ATTRIBUTE THESE LOSSES TO ACIDIC PRECIPITATION ALONE.

THEREFORE, MORE RESEARCH IS NEEDED TO IMPROVE OUR UNDERSTANDING IN THIS AREA BUT THE POTENTIAL FOR ECONOMIC DAMAGE IS GREAT, CONSIDERING THE FACT THAT THE FOREST INDUSTRY IS CANADA'S LARGEST INDUSTRY EMPLOYING ONE OUT OF EVERY TEN WORKING CANADIANS.

SOURCES

ACIDIC PRECIPITATION STUDIES HAVE DEMONSTRATED THAT THE PRECURSORS, SO_2, SULPHATES AND NITRATES, ARE FROM SOURCES WHICH, IN MANY CASES, ARE DISTANT FROM THE SENSITIVE RECEPTOR LAKES. THE SEVERITY OF THIS PROBLEM OF LONG RANGE TRANSPORT INTO ONTARIO BECAME APPARENT TO ONTARIO SCIENTISTS WHEN THEY BEGAN TO ANALYSE THE RESULTS FROM SEVERAL SPECIAL STUDIES, IN PARTICULAR, THE SUDBURY ENVIRONMENTAL AND LAKESHORE CAPACITY STUDIES. BOTH OF THESE GEOGRAPHICALLY

INTENSIVE PROGRAMS MEASURED ATMOSPHERIC POLLUTANTS AND QUANTIFIED THE PROPORTION WHICH, AS A CONSEQUENCE OF VARIOUS PHYSICAL AND CHEMICAL MEANS, ULTIMATELY END UP IN SENSITIVE TERRESTRIAL AND AQUATIC ECOSYSTEMS.

IN PARTICULAR, THESE STUDIES INDICATED THAT, WHEN USING CONTEMPORARY MONITORING AND ANALYTICAL TECHNIQUES, THE SECONDARY OR EVOLUTIONARY POLLUTANTS ASSOCIATED WITH PRIMARY EMISSIONS OF PARTICULATES AND SO_2 WERE BEING DEPOSITED IN LARGE MEASURE BY THE RAIN FALLING OVER EXTENSIVE PORTIONS OF THE PROVINCE. FURTHERMORE, THIS POLLUTED RAIN WAS AND IS SERIOUSLY AFFECTING ONTARIO'S VERY SENSITIVE ENVIRONMENT.

ACID RAIN IS BY DEFINITION A PROBLEM THAT CROSSES BOUNDARIES SINCE THE POLLUTANTS OF CONCERN ARE EMITTED INTO THE ATMOSPHERE AND CAN BE TRANSPORTED OVER GREAT DISTANCES TO THEIR POINT OF DEPOSITION.

THE PRIMARY POLLUTANTS OF CONCERN ARE SULPHUR DIOXIDE AND NITROGEN OXIDES. THE MEMORANDUM OF INTENT WORK GROUP 3B ON EMISSIONS, COSTS AND ENGINEERING ASSESSMENT IN ITS FINAL REPORT PROVIDED A REVIEW OF SO_2 AND NO_x EMISSIONS FOR BOTH CANADA AND THE UNITED STATES.

EMISSIONS OF SO_2 IN THE U.S. WERE ABOUT 24 MILLION TONNES IN 1980, CONSTITUTING A 14.3% REDUCTION FROM PEAK LEVELS IN THE MID-SIXTIES. HOWEVER, UNDER CURRENT REGULATIONS, THESE

EMISSIONS ARE EXPECTED TO DECREASE SLIGHTLY BY 1990 TO 23 MILLION TONNES AND THEN INCREASE TO ABOUT 27 MILLION TONES BY THE YEAR 2000.

TOTAL CANADIAN EMISSIONS OF SO_2 WERE APPROXIMATELY 4.8 MILLION TONNES IN 1980, A 27.3% REDUCTION FROM THE PEAK LEVEL IN 1965. UNDER CURRENT REGULATIONS, TOTAL EMISSIONS OF SO_2 ARE EXPECTED TO DECREASE SLIGHTLY TO 4.4 MILLION TONNES BY THE YEAR 2000.

THE RATIO OF U.S. TO CANADIAN SO_2 EMISSIONS IS 5.3 TO 1 AND RESULTS FROM SIMPLE CLIMATOLOGICAL ANALYSES INDICATE THAT ABOUT THREE TO FIVE TIMES MORE SULPHUR FLOWS NORTH, FROM THE U.S.A. TO CANADA, THAN SOUTH.

IN 1980, NO_x EMISSIONS IN THE U.S. TOTALLED 19 MILLION TONNES AND IN CANADA THEY TOTALLED 1.8 MILLION TONNES. THE RATIO OF U.S. TO CANADIAN NO_x EMISSIONS IN THE EAST IS ROUGHLY 15 TO 1.

UNDER CURRENT REGULATIONS, NITROGEN OXIDE EMISSIONS ARE PROJECTED TO INCREASE OVER THE NEXT TWO DECADES IN BOTH CANADA AND THE UNITED STATES.

ONTARIO'S RESEARCH AND MONITORING PROGRAM

IN AN ATTEMPT TO RESOLVE THE ACIDIC PRECIPITATION PROBLEM, THE ONTARIO MINISTRY OF THE ENVIRONMENT ESTABLISHED THE ACIDIC PRECIPITATION IN ONTARIO STUDY IN 1979. THROUGH THE

ACTIVITIES OF THIS PROGRAM, NUMEROUS TASKS HAVE BEEN INITIATED TO ASSIST IN THE DEVELOPMENT OF ABATEMENT STRATEGIES FOR ONTARIO AND FOR EASTERN CANADA.

ATMOSPHERIC PROCESSES STUDIES

ONTARIO CURRENTLY HAS AN UPDATED SO_2 EMISSIONS INVENTORY FOR NORTHEASTERN NORTH AMERICA WHICH INCLUDES SOURCES OF 100 TONS/DAY OR GREATER. IN ADDITION, A PRELIMINARY NITROGEN OXIDES EMISSIONS INVENTORY IS AVAILABLE. BOTH OF THESE INVENTORIES ARE CONTINUALLY UPDATED SINCE THEY PROVIDE VALUABLE INPUT TO THE ATMOSPHERIC MODELS CURRENTLY UNDER DEVELOPMENT.

AN MOE STATISTICAL MODEL HAS BEEN DEVELOPED AND VALIDATED. IT SIMULATES LONG-TERM DEPOSITION AND IS DESIGNED TO ESTABLISH SOURCE-RECEPTOR RELATIONSHIPS RESULTING FROM THE TRANSPORT OF CONTAMINANTS OVER DISTANCES OF HUNDREDS OF KILOMETERS. A LAGRANGIAN MODEL HAS ALSO BEEN DESIGNED TO SIMULATE DEPOSITION OVER SHORT TIME SCALES AND IS THEREFORE USED FOR EPISODE ANALYSIS.

ANOTHER MODEL UNDER DEVELOPMENT IS A LONG RANGE TRANSPORT EULERIAN MODEL. THIS IS A COMPLEX COMPUTER MODEL WHICH INCORPORATES DETAILED CHEMICAL TRANSFORMATIONS AND DEPOSITION OF ATMOSPHERIC

POLLUTANTS. IT IS DESIGNED TO LINK SOURCE AREAS WITH SENSITIVE RECEPTOR AREAS AND TO STUDY THE INFLUENCE OF SO_2, NO_x, HYDROCARBONS AND OXIDANTS ON ACID RAIN. THE DEVELOPMENT OF THIS MODEL IS BEING CO-SPONSORED BY THE ONTARIO MINISTRY OF THE ENVIRONMENT, ENVIRONMENT CANADA AND THE FEDERAL REPUBLIC OF GERMANY. THE U.S. ENVIRONMENTAL PROTECTION AGENCY HAS ALSO EXPRESSED AN INTEREST IN COOPERATIVE RESEARCH IN THIS AREA. THE MODEL SHOULD BE AVAILABLE FOR APPLICATION BY 1987.

TO ASSIST IN DETERMINING THE DEPOSITION LOADINGS FOR THE PROVINCE, A CUMULATIVE ACID DEPOSITION MONITORING NETWORK WAS ESTABLISHED IN 1980. AS WELL, AN EVENT NETWORK HAS BEEN OPERATIONAL SINCE 1980 TO YIELD INFORMATION ON SOURCE AREAS ASSOCIATED WITH ACID DEPOSITION EPISODES PLUS THE FREQUENCY AND INTENSITY OF SUCH EPISODES.

AQUATIC EFFECTS STUDIES

DETAILED STUDIES ARE BEING CARRIED OUT ON 8 LAKES AND 32 WATERSHEDS IN THE MUSKOKA-HALIBURTON AREA.

CALIBRATED WATERSHEDS ARE THE KEY TO DETERMINING THE CAUSE/EFFECT RELATIONSHIP OF DEPOSITION AND RESPONSE. THEY CAN ALSO GIVE ACCURATE RATES OF CHANGE OF CHEMICAL WATER QUALITY, CAN BE USED TO DETERMINE "ACCEPTABLE" ACID LOADINGS AND WILL SERVE AS LONG-TERM MONITORS OF

THE EFFECTIVENESS OF ABATEMENT PROGRAMS. THE DATA COLLECTED WILL BE USED IN THE DEVELOPMENT AND TESTING OF STREAM CHEMISTRY AND WATERSHED YIELD MODELS AS WELL AS IN THE CALCULATION OF THE MASS BALANCES OF CALIBRATED LAKES.

FIELD PROGRAMS IN THE AREA ARE ALSO CONCENTRATING ON DETERMINING THE BIOLOGICAL RESPONSES TO THE PRESENT CHEMICAL STRESS AS WELL AS DETECTING THE LONG-TERM CHANGES AS ACIDIFICATION OCCURS. STUDIES HAVE BEEN UNDERWAY, BOTH IN THE FIELD AND IN THE LABORATORY, IN ORDER TO DETERMINE ACUTE TOXICITY THRESHOLDS FOR VARIOUS INDIGENOUS FISH SPECIES IN SYNTHETIC SOFT WATER AS WELL AS TO STUDY METALS TOXICITY, ACCUMULATION AND EFFECTS ON SEVERAL FISH SPECIES.

THE RESULTS FROM THE DORSET CALIBRATED WATERSHED RESEARCH WERE USED EXTENSIVELY BY THE CANADA/U.S. MEMORANDUM OF INTENT IMPACT ASSESSMENT WORK GROUP IN WRITING ITS FINAL REPORT, ESPECIALLY FOR THE DEVELOPMENT OF TARGET LOADINGS.

ONTARIO RECENTLY ENTERED INTO AN AGREEMENT WITH THE NORWEGIAN INSTITUTE FOR WATER RESEARCH TO CO-FUND A REVERSIBILITY OF ACIDIFICATION STUDY. THIS STUDY WILL EXAMINE THE EFFECT OF REDUCING ACIDIC PRECIPITATION ON A SMALL CATCHMENT SITE IN AN "ACIDIFIED" AREA OF NORWAY AND COMPARE IT WITH THE RESULTS OF INCREASED ACIDIC

PRECIPITATION IN AN AREA OF NORWAY NOT RECEIVING ACIDIC PRECIPITATION. RESULTS FROM THIS STUDY WILL COMPLEMENT THE DORSET RESULTS AND ASSIST IN DEFINING THE CAPABILITY OF WATERSHEDS TO NEUTRALIZE ACID.

A FIVE-YEAR EXPERIMENTAL PROGRAM TO INVESTIGATE THE FEASIBILITY OF NEUTRALIZING ACIDIC SURFACE WATERS TO PROTECT AQUATIC LIFE IN ONTARIO LAKES WHICH ARE SUSCEPTIBLE TO ACID RAIN AND TO REHABILITATE LAKES ALREADY DAMAGED WAS ANNOUNCED BY THE MINISTRIES OF THE ENVIRONMENT AND NATURAL RESOURCES IN JULY 1981. AS PART OF THIS PROGRAM, BOWLAND LAKE, AN ACIDIC LAKE 70 KM NORTH OF STUDY WAS LIMED IN MID-AUGUST THIS YEAR. THE LAKE IS BEING CLOSELY MONITORED AND RESULTS FROM THIS EXPERIMENT WILL ASSIST IN THE ASSESSMENT OF LIMING AS A TEMPORARY MITIGATIVE MEASURE FOR OTHER LAKES.

TERRESTRIAL EFFECTS STUDIES

ACIDIC PRECIPITATION HAS THE POTENTIAL TO CAUSE SERIOUS AND WIDESPREAD EFFECTS ON TERRESTRIAL ECOSYSTEMS IN EASTERN CANADA. ONTARIO HAS DEDICATED A MAJOR PORTION OF ITS PROGRAM TO THIS AREA.

A BASELINE SURVEY OF SOILS AND VEGETATION WAS PERFORMED THROUGHOUT ONTARIO IN ORDER TO ESTABLISH THE CURRENT STATUS OF THE SOILS AND VEGETATION AND TO ENABLE FUTURE CHANGES TO BE DETECTED.

LABORATORY EXPERIMENTS WITH SIMULATED ACID RAIN ARE BEING CONDUCTED TO DETERMINE THE EFFECTS OF REDUCED pH ON CERTAIN CROP SPECIES SUCH AS RADISH, SOYBEAN AND PEANUTS. A COOPERATIVE EXPERIMENT WITH FIVE U.S. LABORATORIES WAS UNDERTAKEN IN AN ATTEMPT TO STANDARDIZE TECHNIQUES AND PROCEDURES TO DETERMINE THE EFFECTS OF SIMULATED ACID RAIN ON AGRICULTURAL CROPS UTILIZING INDOOR CHAMBERS.

IN ADDITION, LABORATORY EXPERIMENTS ARE ALSO BEING CONDUCTED ON VARIOUS SOILS. FOR EXAMPLE, SOIL SAMPLES ARE BEING TREATED WITH SOLUTIONS OF VARIOUS ACIDS OF INCREASING STRENGTH TO EVALUATE THE ABILITY OF THESE SOILS TO BUFFER AGAINST ACIDIC PRECIPITATION INPUTS.

THE MINISTRY IS CURRENTLY IN THE PROCESS OF INSTALLING AN OUTDOOR EXCLUSION CANOPY FACILITY. THIS SYSTEM WILL EXCLUDE AMBIENT RAIN FOR FIELD PLOTS WHILE DELIVERING RAIN SIMULANTS TO THE PLOTS. ONCE OPERATIONAL, EXPERIMENTS WILL BE CONDUCTED TO DEVELOP DOSE/RESPONSE RELATIONSHIPS FOR ECONOMICALLY IMPORTANT AGRICULTURAL CROPS AND COMMERCIAL TREE SPECIES. THE POSSIBILITY OF UNDERTAKING COOPERATIVE STUDIES WITH U.S. AGENCIES THAT ALSO HAVE EXCLUSION CANOPY SYSTEMS IS BEING INVESTIGATED.

INTENSIVE TERRESTRIAL STUDIES ARE CURRENTLY UNDERWAY AT TWO CALIBRATED WATERSHED SITES IN THE MUSKOKA-HALIBURTON AREA. THIS WORK IS INTEGRAL TO A COMPLETE UNDERSTANDING OF THE LAKE ACIDIFICATION PROCESS. ACIDIC PRECIPITATION MAY HAVE A DIRECT EFFECT ON TERRESTRIAL ECOSYSTEMS, SPECIFICALLY THE REMOVAL OF PLANT NUTRIENTS AT AN ACCELERATED RATE. THESE DIRECT STUDIES WILL ATTEMPT TO DOCUMENT THE RATE AND MAGNITUDE OF NUTRIENT AND HEAVY METAL INPUTS, LOSSES AND INTERNAL CYCLING.

TWO MORE BIOGEOCHEMICAL SITES HAVE BEEN ESTABLISHED IN NORTHERN ONTARIO, ONE AT AGNEW LAKE IN THE VICINITY OF HIGH FALLS IN NORTHEASTERN ONTARIO AND THE OTHER AT HAWKEYE LAKE IN NORTHWESTERN ONTARIO.

THE STUDIES IN NORTHERN ONTARIO HAVE BEEN DESIGNED TO DETERMINE THE EFFECTS OF LONG RANGE ATMOSPHERIC DEPOSITION ON ELEMENT AND NUTRIENT DISTRIBUTION AND CYCLING WITHIN BOREAL ECOSYSTEMS IN THAT PART OF THE PROVINCE.

IN ORDER TO ASSESS THE POTENTIAL EFFECTS OF ACID RAIN ON THE TERRESTRIAL ECOSYSTEM AS QUICKLY AS POSSIBLE, COOPERATION WITH OTHER NATIONS SUCH AS THE UNITED STAES AND WEST GERMANY MUST CONTINUE.

SOCIO-ECONOMIC INVESTIGATIONS

SEVERAL SOCIO-ECONOMIC STUDIES ARE UNDERWAY TO IDENTIFY THE DAMAGES DUE TO ACID RAIN AND TO ESTIMATE THE BENEFITS OF ITS CONTROL. TO DATE, WE HAVE EXAMINED THE EFFECTS OF ACID RAIN ON AQUATIC-BASED RECREATION AND TOURISM, TERRESTRIAL AND AQUATIC RESOURCE SECTORS, AND HAVE SURVEYED BOTH RESIDENTS AND TOURISTS TO ASCERTAIN THE VALUE AND IMPORTANCE THEY PLACE ON ENVIRONMENTAL RESOURCES AFFECTED BY ACID RAIN. WHILE FINDINGS ARE PRELIMINARY, IT IS EVIDENT THAT THERE IS WIDESPREAD CONCERN ABOUT THE EFFECTS AND THE DECLINE IN ENVIRONMENTAL QUALITY. IN ADDITION, STUDIES ARE BEING CONDUCTED TO ASSESS THE COSTS OF ABATEMENT AND MITIGATION.

INFORMATION IN BOTH THESE AREAS IS NEEDED TO DEVELOP A COST-EFFECTIVE ABATEMENT STRATEGY FOR THE PROVINCE, NOT ONLY AS A COMPONENT OF AN OVERALL EASTERN CANADA ABATEMENT PROGRAM, BUT ALSO AS PART OF A STRATEGY TO CURTAIL ACID RAIN IN EASTERN NORTH AMERICA.

IN ORDER TO DEVELOP AND ASSESS ABATEMENT OPTIONS, THE MINISTRY HAS DEVELOPED A COMPUTERIZED SCREENING MODEL. THIS MODEL HAS THE ELEMENTS REQUIRED TO PROVIDE SIGNIFICANT GUIDANCE IN DESIGNING AN ACID RAIN CONTROL STRATEGY WHICH IS SIMULTANEOUSLY THE LEAST COSTLY AND THE MOST ENVIRONMENTALLY EFFECTIVE.

THE UNIQUENESS OF THE PROCEDURE LIES IN ITS COMPREHENSIVENESS. IN ITS APPLICATION TO ACID RAIN, THE MODEL INTEGRATES THE OUTPUT FROM OUR PRESENTLY AVAILABLE, SIMPLE LONG RANGE TRANSPORT MODEL WITH AN INDEX OF AVAILABLE TECHNOLOGIES AND THEIR COSTS FOR EACH SOURCE CONSIDERED.

PUT SIMPLY, FOR ANY DESIRED ENVIRONMENTAL OBJECTIVE, THE ONTARIO MINISTRY OF THE ENVIRONMENT CAN NOW ESTIMATE THE MOST COST-EFFECTIVE WAY OF ACHIEVING THE DESIRED LEVEL OF ACIDIC DEPOSITION AMONG 235 SOURCES IN SEVEN PROVINCES AND 31 STATES. WITH THIS MODEL, THE MINISTRY HAS THE ABILITY TO SEE IN DOLLARS AND CENTS, AS WELL AS IN TERMS OF ENVIRONMENTAL RELIEF, THE EFFECT OF VARIOUS STRATEGIES. IMPORTANTLY, THE MODEL DEMONSTRATES THE NEED FOR JOINT CANADA/U.S. ACTION.

ONTARIO'S CONTROL PROGRAM

ONTARIO, IN ADDITION TO ALLOCATING FISCAL AND HUMAN RESOURCES IN ORDER TO DETERMINE THE EXACT NATURE OF THE ACID DEPOSITION PHENOMENON, WAS ALSO THE FIRST JURISDICTION TO REGULATE SOURCES OF ACID RAIN PRECURSORS BASED ON THEIR CONTRIBUTION TO THE ACID DEPOSITION PROBLEM AND NOT ON LOCAL AIR QUALITY.

ONTARIO CONSIDERED CANADA'S COMMITMENT UNDER THE MEMORANDUM OF INTENT TO BE A SERIOUS ONE AND IMMEDIATELY IMPOSED NEW AND TOUGHER REGULATIONS ON ITS TWO MAJOR SOURCES -- INCO LIMITED AND ONTARIO HYDRO. THESE TWO SOURCES ACCOUNT FOR 70% OF ONTARIO'S TOTAL EMISSIONS.

IN 1980, THE APPROVED LEVEL OF SULPHUR DIOXIDE EMISSIONS AT INCO WAS 3,600 TONS PER DAY. THE COMPANY WAS REQUIRED BY GOVERNMENT REGULATION, A LEGISLATIVE CONTROL WHICH CANNOT BE APPEALED, TO LIMIT EMISSIONS TO 2,500 TONS PER DAY IMMEDIATELY AND BY THIS YEAR TO REDUCE FURTHER TO 1,950 TONS PER DAY. THIS REPRESENTS A REDUCTION OF APPROXIMATELY 70 PERCENT FROM PEAK EMISSION LEVELS AT SUDBURY IN THE 1960s.

THE PROVINCE'S ELECTRICAL UTILITY, ONTARIO HYDRO, IS ALSO UNDER GOVERNMENT REGULATION TO REDUCE ITS EMISSIONS OF SULPHUR DIOXIDE AND NITROGEN OXIDES. THE REGULATION REQUIRES HYDRO TO REDUCE ITS ACID GAS EMISSIONS BY APPROXIMATELY 43 PERCENT FROM 1980 LEVELS BY 1990.

PERHAPS THE BEST EXAMPLE OF HOW ONTARIO'S INDUSTRY IS CO-OPERATING WITH THE GOVERNMENT TO ACHIEVE EMISSIONS REDUCTIONS IS ONTARIO'S NEWEST SMELTER OPERATED BY TEXAS GULF NEAR TIMMINS. THIS ZINC SMELTER HAS A SULPHURIC ACID PLANT THAT CAPTURES 97 PERCENT OF THE SULPHUR DIOXIDE FROM THE GAS STREAM. TEXAS GULF HAS ALSO BUILT A NEW COPPER SMELTER WITH A DOUBLE CONTACT ACID PLANT DESIGNED TO REDUCE SO_2 BY MORE THAN 99 PERCENT. EMISSIONS WILL BE ABOUT FOUR TONS PER DAY, RATHER THAN THE 400 TONS PER DAY THAT WOULD HAVE BEEN EMITTED WITHOUT THE ACID PLANT.

HOWEVER, ONTARIO DOES NOT INTEND TO STOP HERE. THE REDUCTIONS MANDATED FOR INCO AND ONTARIO HYDRO CONSTITUTE THE FIRST STEP IN ONTARIO'S OVERALL ABATEMENT PROGRAM.

WITH THIS FIRST STEP, ONTARIO HAS DEMONSTRATED THAT IT IS POSSIBLE TO START ABATEMENT ACTION IN A RATIONAL MANNER WHICH RECOGNIZES THE UNCERTAINTIES, THE ECONOMIC STAKES, AND THE IMPERATIVE NEED TO PROTECT LARGE AREAS OF NORTH AMERICA NOW, IN ADVANCE OF IRREVERSIBLE DAMAGE.

THROUGH DISCUSSION WITH OTHER GOVERNMENTS AND INDUSTRY, ONTARIO HOPES THAT A CO-ORDINATED AND EFFECTIVE APPROACH TO LONG-RANGE TRANSPORT ISSUES CAN BE ACHIEVED. ATMOSPHERIC STUDIES CLEARLY DEMONSTRATE THAT THE IMPACTS FROM LONG RANGE TRANSPORT CANNOT BE SOLVED BY ABATEMENT ACTION IN ONTARIO ALONE. MAJOR EMISSION REDUCTIONS IN OTHER PROVINCES AND THE U.S. WILL ALSO BE REQUIRED. ONTARIO LOOKS FORWARD TO THE DEVELOPMENT OF LEGISLATION AND REGULATIONS IN OTHER JURISDICTIONS TO ACCOMPLISH THESE EMISSION REDUCTIONS, AND HOPES THAT THESE EMISSION REDUCTIONS, AS WELL AS CO-ORDINATED RESEARCH, WILL BE PART OF AN AGREEMENT BETWEEN THE U.S. AND CANADA WHICH DEALS WITH THE TRANSPORT OF AIRBORNE POLLUTANTS BETWEEN THE TWO COUNTRIES.

STATEMENT OF DR. MYRON F. UMAN

to the

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS OF THE UNITED STATES SENATE

August 25, 1983
Minneapolis, Minnesota

My name is Myron F. Uman. I am Executive Secretary of the Environmental Studies Board of the National Research Council, which is the operating arm of the National Academy of Sciences and the National Academy of Engineering. I was staff director of the Academy committee that wrote the report issued earlier this summer titled ACID DEPOSITION: ATMOSPHERIC PROCESSES IN EASTERN NORTH AMERICA. The chairman of that committee was Jack G. Calvert of the National Center for Atmospheric Research in Boulder, Colorado. Dr. Calvert asked me to extend to you his regrets that he is unable to be here today. In his absence, it is my pleasure to tell you about his committee's report and to answer your questions about it.

In addition to Dr. Calvert, there were seven members of his committee. Their names are listed in the report. The areas of expertise of the members include atmospheric chemistry and physics, meteorology, and modeling. All are actively involved in acid rain research. The members come from universities, from government and national laboratories, and from the private sector.

The committee's task was to prepare a careful review of current scientific understanding of the atmospheric processes involved in the phenomenon of acid deposition in eastern North America.

Acid deposition is the technical term for the fallout from the atmosphere of acids or acid-forming substances in rain, snow, or fog or as gases or dry particles. The common name for this phenomenon is acid rain. Acid deposition is a natural phenomenon in some places. When man-made emissions substantially increase the acidity, we have the potential for a pollution problem.

To understand the problem of acid rain, we have to understand where the materials are coming from, how and in what quantity and form they get to where they are deposited, and what effects they have once deposited. In more technical language, we want to know the sources, fates and effects of these materials. In addition, policy makers want to know the risks of adverse effects, the potential damages, and the costs of various schemes for controlling the sources or of mitigating the effects.

Ideally with all this information in hand, society can decide, through its political processes, what if anything to do about acid deposition. In practice, society is often faced with making this type of decision with only a limited amount of information---and some of that intensely debated. This appears currently to be the case with the phenomenon of acid deposition.

As a panel of scientists organized under the auspices of the National Research Council, the Calvert committee was asked to address only one aspect of the phenomenon: current scientific understanding of the relationships between sources and receivers, between emissions and deposition. The report does not deal with effects of acid deposition; that subject was treated by an NRC report issued in

1981. We also do not weigh costs and benefits of alternative control strategies, so we are not in a position to make recommendations on whether a control program is necessary or desirable.

The subject of our review is nonetheless important because of its practical implications for the decision making process. We need to understand source-receptor relationships to assess the potential benefits of alternative control strategies. For example, if the source-receptor relationship is highly disproportionate (in technical terms, highly nonlinear), a large, expensive reduction in emissions might not result in a comparably large reduction in deposition. This greatly influences the relative costs and benefits of a control program. Source-receptor relationships are also important for the detailed design of control strategies. If, for example, a certain area of sources can be shown to have the predominant effect on a specific ecologically sensitive receiving area, a detailed control strategy can be designed to protect that area. If not, then we may be left with more general control strategies, which might be more expensive in the aggregate.

The report, then, focusses on atmospheric processes that transport emissions away from their sources, transform them into acids, and deposit them. It reviews theoretical understanding, the results of laboratory experiments, the data obtained from observations in the field, and models of the phenomenon based on computer calculations. This subject is a complex one, the scientific evidence has been evolving relatively rapidly, and uncertainties remain. Nevertheless, the committee understood that to make a positive contribution, its role was to make its best scientific judgment about the meaning of current evidence.

The committee is unanimous in the report's findings and conclusions and believes its approach has been cautious and conservative.

The report addresses two questions that are central to the development of acid rain policy. First, will a substantial reduction in emissions result in a commensurate reduction in deposition and second, to what extent are rural receiving areas influenced by small, local sources and larger, distant ones? In other words, will emission controls be effective and how important is long-range transport of pollution from major source regions?

The committee believes it is possible to give some answers to these questions, but they are limited answers. For example, we know comparatively much more about the relationship between emissions of sulfur dioxide gas and deposition of sulfate ion, as in sulfuric acid, than about the relationships between emission of oxides of nitrogen and deposition of nitrate ion, as in nitric acid. We also know more about average relationships, say averaged over a year or more, than about specific events or episodes. We know more about phenomena in eastern North America than elsewhere on the continent because monitoring and research efforts have focussed primarily on this region.

With these general cautions in mind, our findings can be summarized as follows:

While emissions of pollutant gases do not vary much from day-to-day, acid deposition is highly variable. This is because atmospheric processes such as large-scale transport of air masses, atmospheric mixing near the Earth's surface, and physical and chemical reactions among atmospheric constituents determine where and how emissions are deposited. These processes are highly variable, particularly in the parts of eastern North America believed to be ecologically sensitive to acid deposition. This variability complicates the analysis of source-receptor relationships.

While it has been hypothesized based on analyses of European data that the relationship between long-term average emissions and deposition is nonlinear, using the same type of analysis on North American data we find no evidence for a strong nonlinearity in this relationship. Our finding is based on analysis of historical trends in emissions and in deposition at one location in New Hampshire (the only reasonably reliable historical record in North America), on the analysis of the ratios of pollutants in emissions and deposition, and on comparison of the percentages of emissions of sulfur dioxide and oxides of nitrogen that are deposited as sulfate and nitrate in precipitation.

The finding is supported by theoretical calculations taking account of the latest results of realistic laboratory studies. In these studies, the chemical process widely hypothesized to introduce strong nonlinearity in the source-receptor relationship has been found not to be important in polluted atmospheres typical of eastern North America.

The report uses the phrase "no evidence of a strong nonlinearity," Why did the committee phrase its finding this way and what does it mean ?

Let me explain. Strictly speaking, the relationship between emissions and deposition is either linear or nonlinear. If it is linear, a change in emissions would result in a proportionate change in deposition. That is, if the relationship were linear and if a reduction in emissions of 20 percent would lead to a reduction in deposition of, say 18 percent, then a reduction in emissions of 40 percent would lead to a reduction in deposition of 36 percent. If this were the case, the constant of proportionality in the linear relationship would be 0.9. If the relationship were nonlinear, a change in emissions would result in a disproportionate change in deposition--or maybe even no change at all.

Now we know that many atmospheric processes are in fact nonlinear. For example, the relationship between concentrations of ozone and other photochemical oxidants in heavily polluted urban atmospheres and emissions of the precursor gases from which the ozone is formed (hydrocarbons and oxides of nitrogen) is known to be nonlinear; this nonlinearity contributes to the difficulties that have been experienced in controlling urban smog in some locations. More to the point, historical data on acid deposition in Europe and a simple chemical theory developed in 1981 to describe the data have been widely used as a model for nonlinearity between emissions and acid deposition.

The committee started therefore from the assumption that the relationship in North America was also nonlinear and set about to determine how important the nonlinear processes are on the average. The committee looked for important nonlinearities in the available data and, within the limits of uncertainty associated with errors in the data and in estimating emissions, found none. This means that within the uncertainties and for average values and over large areas of eastern North America, the source-receptor relationship can be taken for practical purposes as essentially linear.

What then is the relative importance of long-range transport from distant sources? Theoretical and observational evidence exists for the long-range transport of air pollutants leading to acid deposition. There is little doubt of this. However, based on its analyses of both the available data and current available computer models of long-range transport, the committee concluded that the relative importance of long-range transport and the influence of local sources cannot be determined with reasonable certainty at this time.

Computer calculations of the long-range transport of the pollutants that lead to acid deposition currently are only very approximate; the committee concluded that the models are not sufficiently reliable at this time to provide realistic quantitative assessments of source-receptor relationships over long distances.

Of course, common sense suggests that if two identical sources were located upwind of a sensitive area, on average the closer source would have the larger effect on that area. But in most cases of concern about acid deposition, we do not have identical sources close to and far from sensitive areas. Rather, we have situations in which the nearby sources emit relatively small amounts of precursors while the largest emitters are relatively far from sensitive areas.

Based on its study, the Calvert committee concluded that reliable assessments of the relative importance of nearby and distant sources for deposition at specific locations would have to await the results of carefully planned and executed field studies that are needed to develop and validate transport models. Of particular importance are studies of the motion of air parcels under meteorological conditions typical of eastern North America. It will likely take several years of such studies before we can get a more refined picture of the influence of specific source areas on specific receptor areas.

How might our findings be applied to the analysis of alternative control strategies? On the basis of our spatial analysis of the ratios of pollutants in emissions and deposition, we would expect that if SO_2 emissions were changed throughout eastern North America in such a way that the spatial pattern of emissions is unchanged, a similar change would occur in the deposition of sulfate. The analysis is limited to circumstances in which the spatial distribution is unchanged because we cannot rely on current models to determine the relative importance of specific source areas on specific receptor areas. This means that we cannot predict what might happen at a specific receptor site if emissions in one area of sources were reduced by a larger percentage than emissions in other areas.

Our findings, while important, have only limited applicability. We believe the report demonstrates that a uniform reduction in emissions of SO_2 would lead to a proportionate, uniform reduction in deposition of sulfates (with a constant of proportionality close to 1.0). We do not intend by this statement to imply that the policy of uniform emission reduction is the best one to adopt. Obviously, recommendations on control policy should be based on a variety of considerations that we have not studied, including benefit and cost analyses. The report can also be interpreted to suggest that if substantial reductions in SO_2 emissions were made non-uniformly within the study region, the integrated total deposition of sulfates in the region would be proportionately reduced; in this case, however, we cannot state quantitatively how large a reduction in deposition would occur in specific locations within the area.

This concludes my presentation. I will be happy to discuss any aspect of the committee's report with you including, if you wish, some of the more detailed technical evidence presented in the report. Thank you.

Statement by Gary E. Glass
Environmental Research Laboratory
U.S. Environmental Protection Agency
6201 Congdon Boulevard
Duluth, MN 55804

To the Senate Committee on Environment and Public Works,
Robert T. Stafford, Chairman, at 9:00 A.M. August 25, 1983 at the
Minnesota Pollution Control Agency, 1935 West County Road B-2,
Roseville, Minnesota.

> It is EPA policy that we base our formal scientific judgment on peer-reviewed materials. Only through the preservation of the peer review process can the integrity of the scientific judgment of the Agency be maintained. ~~Since much of my statement relies on material and reports that have not been peer reviewed, EPA as an Agency cannot support any conclusions or opinions that I have drawn. As a result, I am offering this statement including opinions and conclusions as my own personal scientific judgment~~. 1/

This statement has been prepared in response to your invitation of August 18, 1983 to specifically address the following topics:

1. The nature and extent of areas within the upper Midwest sensitive to acid deposition;
2. The probable sources of pollution which give rise to deposition in those areas;
3. The impacts, if any, of deposition in such areas; and
4. The means by which such deposition could be reduced.

I thank you for this invitation and the opportunity to present our findings concerning acid rain in the upper Midwest. I have been employed at the Environmental Research Laboratory-Duluth as a research chemist since 1968 after completing the Ph.D. and post doctorate training at the University of Minnesota, Minneapolis and University of Wisconsin, Madison, respectively. I presently serve as Chief of the Energy/Environment Research Branch and have been conducting research on the total environmental impacts of fossil fuel combustion since 1975.

Our information database comes from studies, designed to assess the susceptibility of aquatic and terrestrial resources to damage from airborne pollutants, that were mostly begun in 1979 by ERL-D and its cooperators and in which I have been directly involved as investigator and project officer. Partial results have been published from the 1979-1981 work (1-31), while others are in review (32-37) and planned (38-55) from work carried out in 1980-1983. The interpretation of some of the results is still underway and in review (32-37).

The information presented here in final form (having undergone extensive peer review) is published or is approved for publication (1-33, 35-37). References 38-55 refer to reports and manuscripts that are being written and, as such, have not been peer reviewed.

NATURE AND EXTENT OF ACID SENSITIVE AREAS

The present and future impacts of acidic deposition in the upper Midwest region must be assessed on the following basis:

1. The presence of the most freshwater related resources in the entire U.S. including the largest volume and area of freshwater, tens of thousands of freshwater lakes, thousands of miles of freshwater streams, and abundant, indigenous fish and wildlife;

1/The mark on this paragraph was made by Mr. Glass and is referred to at p.37

2. The presence of several million acres of national forest, park and wilderness areas with abundant, indigenous wildlife, and heavy recreational and commercial usage; and

3. The presence of meteorologic, hydrologic, and watershed component characteristics that make these aquatic and terrestrial resources especially vulnerable to acid alteration and related impacts.

The properties of freshwater that make its quality resistant to acid alteration are the presence of acid neutralizing (or buffering) and metal complexing substances. The acid neutralizing substances are measured in terms of the concentration of alkalinity in the water and are expressed as grams or equivalents of calcium carbonate (an acid neutralizing chemical compound) per liter of water. The response of freshwater samples from wilderness and park areas of Minnesota to added acid is shown in Figure 1 (2). The freshwater response to acid, added as hydrogen ion, H^+, is expressed as pH, the negative logarithm of the resulting concentration in the sample. Lake samples with varying amounts of alkalinity respond differently to acid addition. Low alkalinity samples respond rapidly and are vulnerable to change as compared with samples that are high in alkalinity.

The exact number of lakes and streams in the upper Midwest that have freshwater concentrations of low alkalinity are not known. Surveys of representative areas within the region have been undertaken to estimate the numbers and to determine the factors that control freshwater alkalinity (2, 4, 37) in the sites shown in Figure 2 over the periods 1978-1983, Table 1. The findings are shown in Figures 3, 4, 5 and summarized in Table 2. The groupings of alkalinity concentrations are based on a sensitivity classification used by Work Group I of the US/Canada Memorandum of Intent on Transboundary Air Pollution (56) and are given in Table 3.

Other factors, in addition to freshwater concentrations of alkalinity, have also been found to be important in controlling water quality (27). They are mainly related to the hydrologic flow of water through the watershed and the characteristics of terrestrial components, soil, and sediments of the watershed that neutralize acids and mobilize metals into pollutants. The differing hydrologic aspects of lakes are pictorially described in Figure 6 and represent a continuum of flow conditions. The most sensitive are of two hydrologic types, the first is where the lake surface area defines the watershed area for receiving the total water budget of the lake and has a flow-through time of years; the second type has a rapid water flow-through time with a larger watershed area where surface flow of water input is from non-calcareous bedrock that dominates the hydrologic flow with little or no groundwater input.

An example of this second type has been studied in Minnesota adjacent to the Boundary Waters Canoe Area Wilderness (BWCAW) (10,11). The effect of snowmelt on Filson Creek and Omaday Lake was observed during 1979 where the pH of the stream decreased from 6.6 to 5.5, Figure 7 (14). The alkalinity changes in the creek during snowmelt reflect simple dilution of stream flow, but depression of pH values to less than 5.7 indicates that the base flow (pH ~6.5) has been diluted with melt water that contains some concentrations of acidifying mineral acids (56).

Areas within the upper Midwest show different distributions of lake hydrologic types, see Table 4 (37), and are expected to exhibit varying sensitivity to acid deposition on this basis.

A description of all factors responsible for every type of surface water alteration by acid deposition may never be known (14) but the dominant controlling factors for northcentral Wisconsin are known, Table 5 (27) and are being identified in the upper Midwest (39, 40, 41, 45, 46, 51, 52).

The proportion of lakes in the upper Midwest that are thought to be directly vulnerable to acidic deposition, at this time, is about 10%. But considering the large total number of lakes in the region, the number of vulnerable lakes may be estimated to be about 5,000 to 10,000. This estimate will be refined as the full syntheses of the data base are completed during the coming year.

Among the important hydrologic and meteorologic aspect of acidic deposition to the upper Midwest is the impact of snow melt. As seen in Figure 7, stream water quality is dominated by large hydrologic events. Snow accumulation of pollutants throughout the winter season is followed by the spring snow melt that releases a large concentrated dose of pollutants over a short time. This process is believed to increase the vulnerability of aquatic resources in the upper Midwest compared with regions of North America where winter accumulation of pollutants does not occur. The first melt-water of snow contains the greatest concentration of accumulated pollutants, see Figure 8 (14), due to their alteration of the freezing point of water. These acid concentrations are large enough to mobilize soil and sediment components into pollutants (5, 7) in some regions.

The long distance transport of airborne pollutants into the upper Midwest is generally expected to follow the surface streamlines for continental wind patterns, Figure 9 (14). The future development of fossil fuel is expected to take place in the upper Midwest's "airshed", up-wind, where the western states' and provinces' energy developments are found. These developments and subsequent emissions could add substantially to the airborne pollutant deposition currently observed and are a factor in defining the vulnerability of the resources at risk in this region. This may be especially true for substances such as mercury where residues in fish are already observed to exceed FDA guidelines in some Minnesota and Wisconsin lakes (2, 48).

ACIDIC DEPOSITION IN THE UPPER MIDWEST

An important objective of the ERL-D studies has been to identify the airborne pollutants present in precipitation and to monitor their concentrations over time. The first results of this effort are summarized for wet deposition for hydrogen ion as pH in Figure 10 and for other components in Tables 6 and 7 which compare these concentrations and depositions with other regions of the world where few emission sources exist or where demonstrable impacts have been observed. Similar acidic deposition is observed at the Fernberg Road monitoring site adjacent to the BWCAW and compared with Narbuvollen, Norway where loss of lake fishery has been observed. No such resource loss of fishery has been expected in the BWCAW due to differences in watershed sensitivities and the relatively low level and recent onset of acidic deposition in the western part of the region; although some observed changes (10, 11, 30, 37, 46, 49) in precipitation and water quality could cause stress in these sensitive ecosystems (2, 14, 33, 56). The opposite is true for the eastern part of the upper Midwest region where impacts are expected (14, 56) because of the relatively high level acidic deposition (32).

The dry deposition of acidic components can make a significant contribution to the total atmospheric loading to a watershed. The emission sources within a region are expected to be the major contributors to the deposition of that region. For the northeastern Minnesota region shown in Figure 11 (19, 23) about 100,000 tons per year of SO_2 (20% of Minnesota's total) were emitted by 37 sources for the year 1976. Calculations by models indicate that about 25% of this quantity is deposited (90% dry, 10% wet) in and 75% blows out of the region shown (19). Thus the dry deposition of acid-forming pollutants in this region could additionally contribute between 10 to 60% to the wet sulfur deposition and between about 30 to +100% to the wet acidic deposition depending upon the location and proximity to emission sources.

Monitoring of both wet and dry deposition is underway at the Fernberg Road site (BWCAW) as part of the ERL-D cooperative monitoring program between the United States Forest Service, the Minnesota Pollution Control Agency, and the Ontario Ministry of the Environment. In other regions of the upper Midwest snow pack measurements are used to measure the total wet plus dry deposition of airborne pollutants (2, 11, 19, 37, 46, 53).

The actual and potential impact assessment from airborne pollutants should consider the total concentrations and deposition of acid-forming substances, including hydrogen and ammonium ions. These components must also be evaluated in conjunction with the hydrologic regime of the water body and the metabolism of nitrate and in some cases sulfate ions, primarily by plants, to release acid-neutralizing components in some regions of the watershed ecosystem. The complex dose-response relationships are being studied (45, 46, 51, 52) and early results have been reported (5, 9, 10, 12, 18, 20, 21, 22, 25, 26).

IMPACTS OF ACIDIC DEPOSITION

The most clearly documented impacts of acidic deposition are in the altered quality of rain and snow, see Figures 8 and 10 in above sections (2, 3, 11, 14, 19, 24, 32, 37, 45, 46, 53, 56). High quality precipitation water must be maintained for the satisfactory recharge of surface and ground water.

The framework for documenting and understanding the probable responses in freshwater quality of lakes following the emission of strong acid-forming compounds to the atmosphere resulting in significant sulfuric (H_2SO_4) and nitric

(HNO_3) acidic deposition and acid concentrations has been summarized by the lake "titration" model of Henriksen (58), Figure 12. The straight line indicates the reduction of pH as the alkalinity is titrated (used up) by the addition of acid. The curved line shows the best estimate of the pH response of lakes during an equivalent addition of acid. The curved portions of the lake response line reflect more sources of acid neutralizing or buffering substances present; and at low pH, metals, such as aluminum, have been dissolved out of the soil and sediments and contribute to "acid buffering". This relationship is a simple model for the actual complexities of watershed titrations, but it has been successfully applied in a generalized fashion using a nomograph shown in Figure 13 (56, 59).

The first application of the Henriksen nomograph to data from the upper Midwest is shown in Figure 14, indicating that a substantial number of lakes in Wisconsin and Michigan may be called "acidified" using Henriksen's criteria, while others may be labeled as in "transition". An earlier version of the Henriksen model also indicated the presence of "acidified" lakes in Wisconsin (3). The assumptions made by the Henriksen approach are being evaluated and an improved version of the model is planned for the upper Midwest (45).

The observed, statistically significant, reduction (or loss) of lake water alkalinity after snowmelt in a majority of northern Minnesota lakes studied is shown in Figures 7 and 15. Similar data have been collected in Wisconsin and Michigan and will be analyzed in conjunction with snow-pack accumulation over several years of record. These analyses should yield quantitative total watershed dose-lake water response information for the upper Midwest region (46).

A large percentage and number of vulnerable lakes in the upper Midwest region are experiencing ecosystem stress when the USEPA water quality criteria for the protection of aquatic life are considered. The distribution of lake pH and alkalinity for the study lakes in the upper Midwest are shown in Figure 17 (37). The solid line at pH 6.5 indicates the lower bound of pH where a "full diversity" of aquatic organisms are known to abound. Reducing the pH below 6.5 causes ecosystem stress resulting in decreasing diversity and the extinction of sensitive aquatic species, Figures 18 and 19 (14, 33). Below a pH of 5.8, major impacts have been recorded including the loss of fisheries (56).

The most obvious, but most difficult, method to evaluate the impacts of acidic deposition in the upper Midwest is the use of time-trend data and historical records. Due to the unique data available for northcentral Wisconsin lakes for the period 1926-1941, an in-depth study of historical trends there has been underway since 1980. The first results are shown in Figure 20 (34) where differences in analytical and methodological aspects have been resolved. The results indicate that the specific conductivity, a measurement related to the concentrations of dissolved salts, has increased for most lakes. The alkalinity comparisons show a mixed response, with a majority of the lakes increasing in alkalinity where land-use changes dominate the watershed and a minority of lakes decreasing in alkalinity where water quality is controlled mainly by precipitation quality. Historical pH changes are the most difficult to interpret and show the highest variability for this data set. Comprehensive analysis of these data are underway and are scheduled for completion within 6 months (54).

The evaluation of recent time trend data, Table 1, originally scheduled for 1983 is now planned for 1984 (37, 45, 46, 51). This data base is unique because of its comprehensiveness, quality assurance, and chain of custody aspects, and is methodologically consistent internally.

REDUCTION OF ACIDIC DEPOSITION IMPACTS

The strong acid-forming airborne pollutants have been identified as originating from sulfur, nitrogen, chloride and fluoride compounds formed from fossil fuel combustion as precursors to the formation of acidifying ions, hydrogen and ammonium. The general reduction of emissions will obviously reduce total deposition as what goes up comes down and may reduce the resultant impacts. Other aspects being equal, priority for emission reductions may be justified as fluoride > chloride > sulfur > nitrogen due to ecosystem processes (primarily plant metabolism) yielding acid-neutralizing compounds from nitrate and, under some conditions, sulfate. Chloride and fluoride do not undergo these reactions and fluoride is phytotoxic.

A reduction of local emission sources, with low stacks burning high sulfur fuels, will have a greater positive impact on reducing total acid-forming deposition to an adjacent sensitive area compared with reductions of emissions at sources located at greater distances with tall stacks (19).

A measure of local relief to acid stress may be accomplished by adding acid neutralizing compounds to lakes and streams with small watersheds, but these measures must be viewed as short-term solutions requiring frequent renewal. Greater success may be predicted for lakes that are hydrologically dominated by precipitation quality and where little or no mobilization of soil and sediment metal components is observed. Little or no relief will be obtained where large quantities of metals are mobilized from watershed soil components, or where indirect impacts are observed such, as atmospheric mercury scavenging and deposition resulting in elevated fish tissue residues, or where impacts occur from direct deposition of acidic gases, particules, fog, mist or dew.

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Table 1

Inventory of Lake, Stream and Well Sites Studies through Spring 1983 by ERL-D and Contained within the Database (Total Sites/Visits, and Replicate Samples by Year and Season).

	N. Minnesota/ Ontario			N. Wisconsin			N. Michigan/ Ontario		
	Sites	Visits	Replicates	Sites	Visits	Replicates	Sites	Visits	Replicates
1978/79									
W	26	26	0						
S	31	55	3	0	0	0	0	0	0
S	15	52	19	0	0	0	0	0	0
F	102	118	63	0	0	0	0	0	0
W	13	15	0	0	0	0	0	0	0
S	161	500	26	1	1	0	0	0	0
S	31	84	17	349	369	47	0	0	0
1979/80									
F	8	17	4	133	142	15	0	0	0
W	0	0	0	1	2	0	0	0	0
S	40	62	29	145	146	21	0	0	0
S	0	0	0	154	987	78	1	5	6
1980/81									
F	8	8	1	21	21	2	0	0	0
W	4	15	15	0	0	0	0	0	0
S	265	275	87	31	36	8	0	0	0
S	0	0	0	14	64	32	1	1	0
1981/82									
F	12	23	8	32	87	15	0	0	0
W	7	12	9	48	77	18	62	69	21
S	29	142	36	51	93	37	79	199	50
S	12	18	2	68	83	20	0	0	0
1982/83									
F	13	13	2	28	41	10	16	16	4
W	1	1	0	17	47	10	0	0	0
S	67	173	39	32	49	14	22	22	5
S[a]	16	16	3	16	16	3	16	16	3
Totals									
F	111[b]	179	78	151[b]	29	42	16[b]	16	4
W	46	69	24	54	126	28	62	69	21
S	480	1207	220	176	325	80	87	221	55
S	57	154	38	496	1503	177	2	6	6

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[a] Scheduled for July 25 - August 12, 1983; not included in totals.
[b] Unique sites within season.

Table 2

A Summary of the Number of Lakes and Streams, and the Frequency Distribution of these Sites in Five Alkalinity (Sensitivity) Classes

Region		Alkalinity Interval					Total Sites
		<0	0-39	40-199	200-499	500+	
Minnesota-Ontario	%	0.2	0.2	41	37	22	46
	Count	1	1	186	166	100	454
Wisconsin	%	3	23	23	24	28	45
	Count	13	100	99	105	121	438
Michigan-Ontario	%	12	10	19	17	42	9
	Count	11	9	17	15	38	90
Totals	%	2.5	11.2	30.8	29.1	26.4	100
	Count	25	110	302	286	259	982

Table 3. Lake Alkalinity Groupings and Acid Sensitivity Classification

Grouping	Alkalinity range
Acid	<0 ueq/1
Extremely sensitive	0-39 ueq/1
Sensitive	40-199 ueq/1
Moderately sensitive	200-499 ueq/1
Not sensitive	500+ ueq/1

Table 4

Regional Differences in Hydrologic Lake Type

REGION	SEEPAGE & INFLOW	DRAINED	DRAINAGE & IMPOUNDMENT	SPRING
N, Minnesota N = 266	9%	-0-	70%	21%
N, Wisconsin N = 275	43%	3%	43%	11%
N, Michigan N = 126	56%	-0-	33%	11%

Table 5

Relative Importance of Terrigenous Factors in Lake Susceptibility for 275 N. Wisconsin Lakes* as Indicated by Rank Correlation Coefficients and Percent Separation for Discriminant Functions I and II

Variables	Discriminant Function I	Discriminant Function II
Morphometric Factors		
Lake Area	0.48	0.01
Watershed Area	0.34	0.45
Mean Depth	-0.24	-0.36
Watershed Area/Lake Area	0.30	0.26
Hydrologic Type		
Seepage	-0.99	0.04
Drained	0.12	0.24
Drainage	0.68	0.04
Spring	0.31	-0.48
Impounded	0.20	0.36
Geology		
Moraine Tills	-0.29	-0.20
Outwash (ground and end)	0.29	0.20
Depth to Bedrock	-0.33	0.49
Vegetation Type		
Agricultural, Urban, Other	-0.12	-0.14
Bog and Forest	0.26	0.49
Deciduous	-0.19	-0.15
Coniferous and Deciduous	0.06	-0.25
Soils		
Loams and Silt Loams	0.01	0.27
Sand	-0.01	-0.27
Percent Separation	89	11

*Values greater than 0.13 are significant at ($P<0.05$)

Table 6

Volume-Weighted Annual Average Concentrations of Major Cations and Anions in Weekly Composite Precipitation Samples

January - December 1981[1]

	Precip. (cm)	n[2]	μeq/1					
			SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	Mg^{2+}	H^+(pH)
Lamberton, MN	52.7	35	36	24	42	23	8	4.0 (5.40)
Marcell, MN	77.8	44	29	18	19	14	6	7.9 (5.10)
Fernberg, MN	67.8	41	30	17	18	10	5	13 (4.89)
Spooner, WI	73.4	31	47	22	32	13	5	20 (4.70)
Trout Lake, WI	72.0	44	35	18	20	11	4	16 (4.80)
Pellston, MI	65.4	42	54	29	18	14	6	40 (4.40)
Wellston, MI	76.8	43	63	32	25	14	5	50 (4.30)
Kellogg, MI	82.1	38	70	30	25	16	6	50 (4.30)
Denali (McKinley National Park), AK	38.1		12	2.6	2.3	5.5	5.2	3.2 (5.49)
West Glacier (Glacier National Park, MT	75.8		19	6.6	3.9	8.6	3.9	10 (5.00)
Hubbard Brook, NH	149.6		49	21	12	6.5	3.6	50 (4.30)
Huntington, NY	101.8		53	26	16	10	4.1	40 (4.40)
Aurora, NY	94.8		100	49	66	16	7.7	79 (4.10)
Birknes, Norway[3]	146.6		71	41	42	9	12	69 (4.16)
Narbuvollen, Norway[3]	41.7		28	13	11	11	2	22 (4.66)

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[1] Data from individual site operators as preliminary NADP site reports.

[2] n = number of weekly precipitation samples collected.

[3] Mean annual concentration, daily bulk sample, 1977-1979, from (3).

Table 7

Annual Deposition of Major Anions and Cations Measured in Weekly Composite Precipitation Samples

January - December 1981

	Precip. (cm)	equivalents/hectare						
		SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	Mg^{2+}	H^+	$H^+ + NH_4^+$
Lamberton[1]	52.7	219	150	228	145	56	21	249
Marcell[1]	77.8	226	136	144	107	42	68	212
Fernberg[1]	67.8	221	119	126	76	37	90	216
Spooner[1]	73.4	349	171	251	102	35	114	365
Trout Lake[1]	72.0	253	134	139	74	27	122	261
Pellston[1]	65.4	353	190	123	97	44	247	370
Wellston[1]	76.8	477	251	186	108	45	370	556
Kellogg[1]	82.1	554	243	197	124	46	381	578
Denali (McKinley National Park), AK[1]	38.1	51	12	10	24	22	13	23
West Glacier (Glacier National Park), MT[1]	75.8	162	55	34	75	35	80	114
Hubbard Brook, NH[1]	149.6	758	325	181	104	56	711	892
Huntington, NY[1]	101.8	550	260	161	97	42	450	611
Aurora, NY[1]	94.8	847	383	288	143	55	716	1003
Birknes, Norway[2]	147.6	1041	601	616	132	176	1011	1628
Narbuvollen, Norway[2]	41.7	117	54	46	46	8	92	138

[1] Data from NADP site operators.

[2] Mean annual values 1977-1979 for daily bulk samples (3).

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Figure 13. Nomograph to predict the pH of lakes given the sum of nonmarine calcium and magnesium concentrations (or nonmarine calcium concentration only) and the nonmarine sulphate concentrations in lake water (or the weighted-average hydrogen ion concentration in precipitation) from Henriksen, 1982, adapted from MOI 1983 (56,59).

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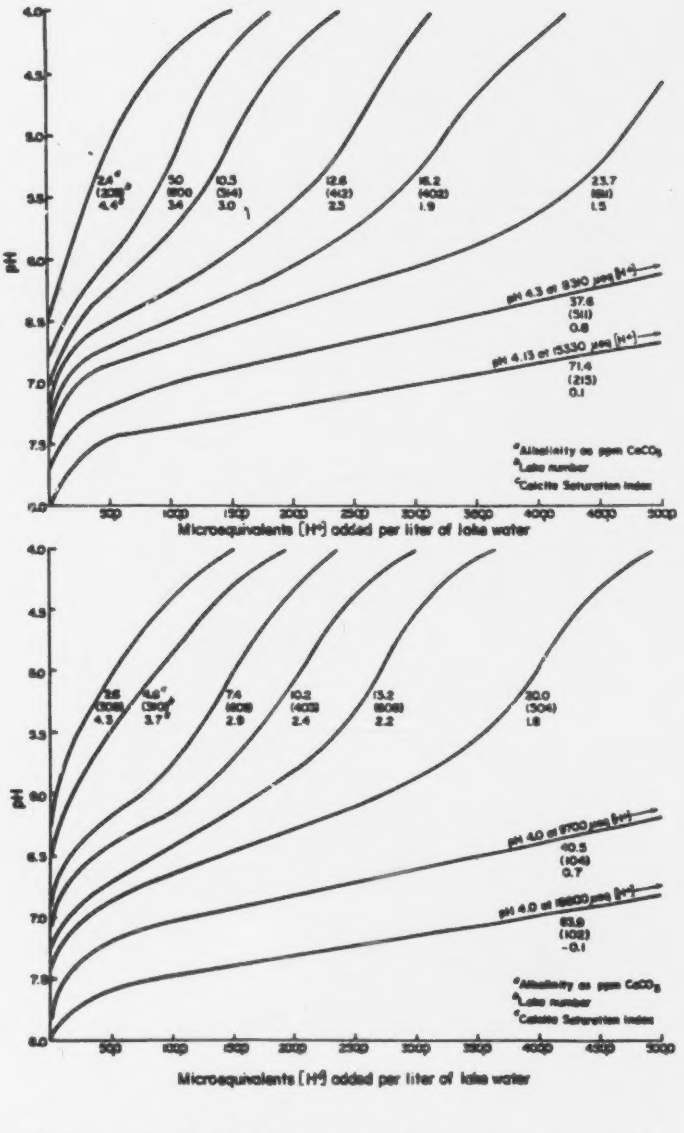
Figure 20. Water quality changes in northern Wisconsin lakes. Historic measurements are adjusted using: a) $20^{o}C$ to 25^{o} using 2.3%/^{o}C; b) -64 euq/l MOA to TIP; and d) pH = 1.19-1.17 (pH, colorimetric) from Eilers et al., 1984 (34).



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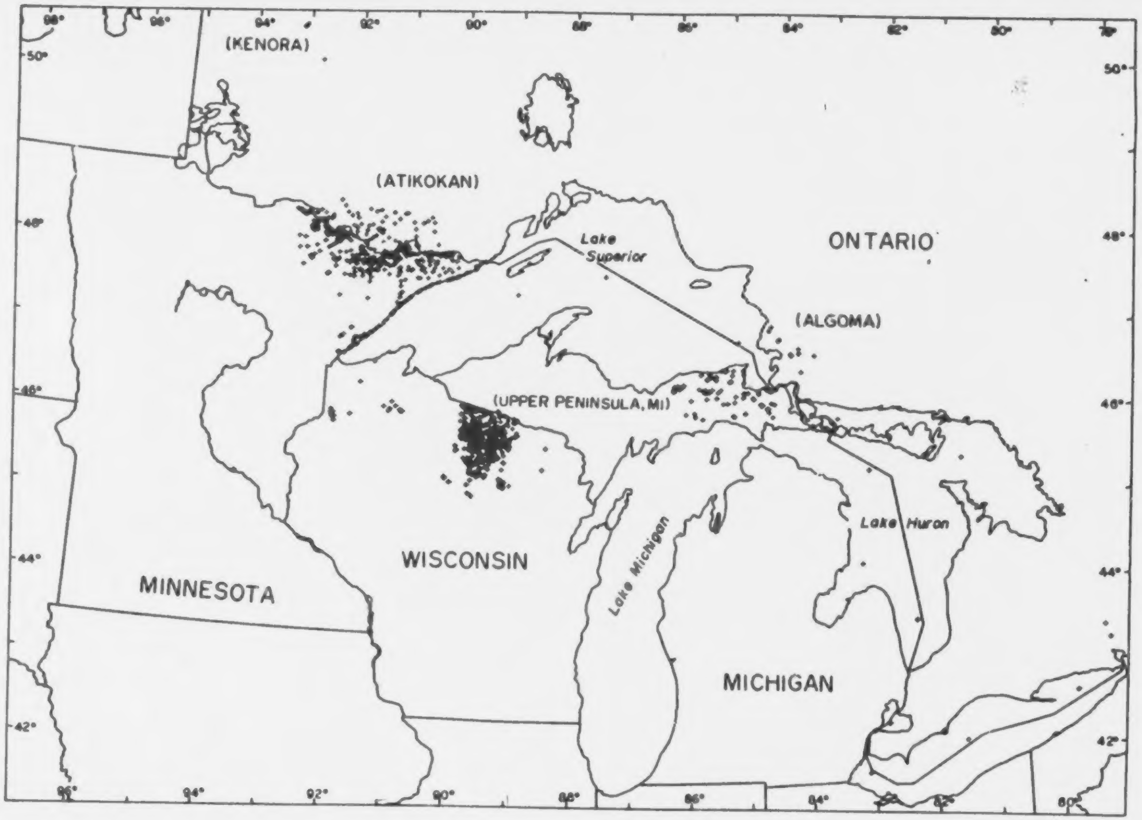
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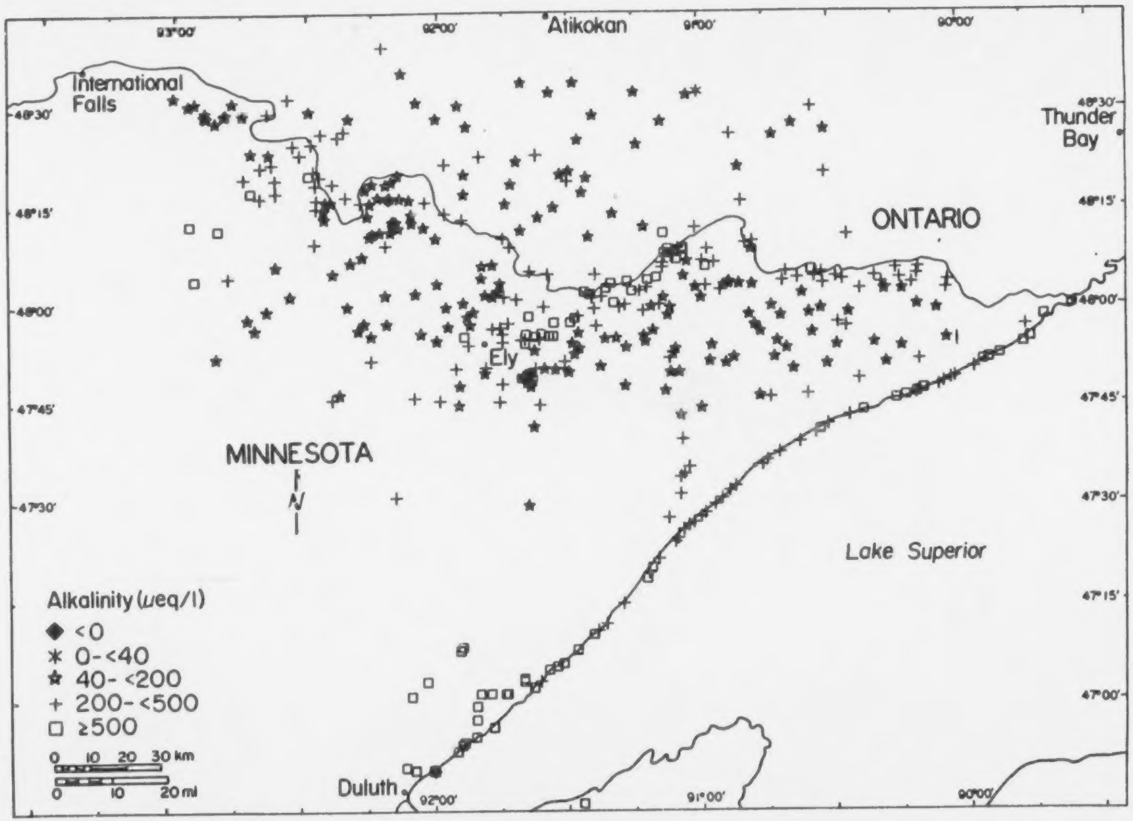
Lake Superior
(ALGOMA)
(UPPER PENINSULA, MI)
Lake Huron
Lake Michigan
MINNESOTA
WISCONSIN
MICHIGAN

Figure 2. General distribution of ERL-D lake and stream sampling sites for assessment of surface water sensitivity in the Upper Great Lakes States from Glass et al., 1983 (37).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47°15'
47°00'
ONTARIO
Ely
MINNESOTA
N
Lake Superior
Duluth
Alkalinity (µeq/l)
◆ <0
✱ 0-<40
★ 40- <200
+ 200- <500
□ ≥500
0 10 20 30 km
0 10 20 mi

Figure 3. Distribution of sites and broad alkalinity classes for lakes in Minnesota/Ontario from Glass et al., 1983 (37).

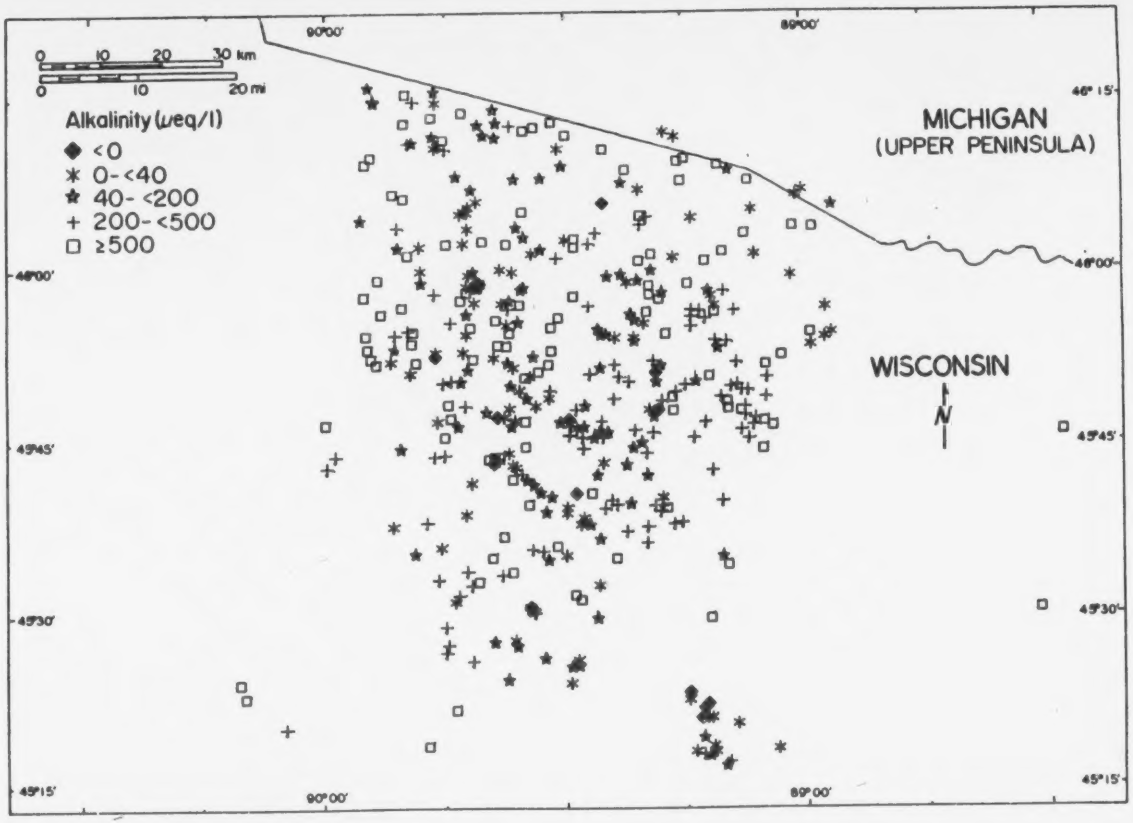

0 10 20 30 km
0 10 20 mi
Alkalinity (μeq/l)
◆ <0
✱ 0-<40
★ 40- <200
+ 200-<500
□ ≥500
MICHIGAN
(UPPER PENINSULA)
WISCONSIN
N
90°00'
89°00'
46°15'
46°00'
45°45'
45°30'
45°15'

Figure 4. Distribution of sites and broad alkalinity classes for lakes in Wisconsin from Glass et al., 1983 (37).

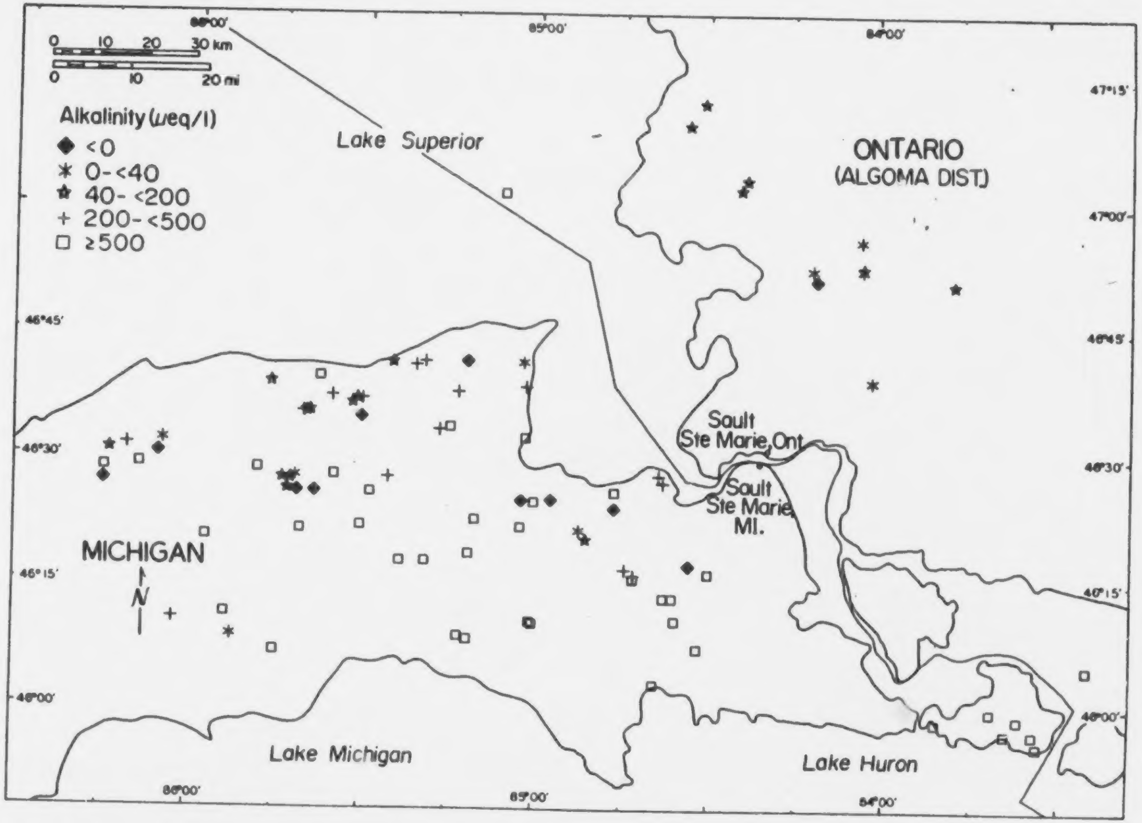

0 10 20 30 km
0 10 20 mi
Alkalinity (μeq/l)
◆ <0
✳ 0-<40
★ 40-<200
+ 200-<500
□ ≥500
Lake Superior
ONTARIO
(ALGOMA DIST)
Sault Ste Marie, Ont
Sault Ste Marie, MI.
MICHIGAN
N
Lake Michigan
Lake Huron
86°00'
85°00'
84°00'
47°15'
47°00'
46°45'
46°30'
46°15'
46°00'

Figure 5. Distribution of sites and broad alkalinity classes for lakes in Upper Michigan/Ontario from Glass et al., 1983 (37).

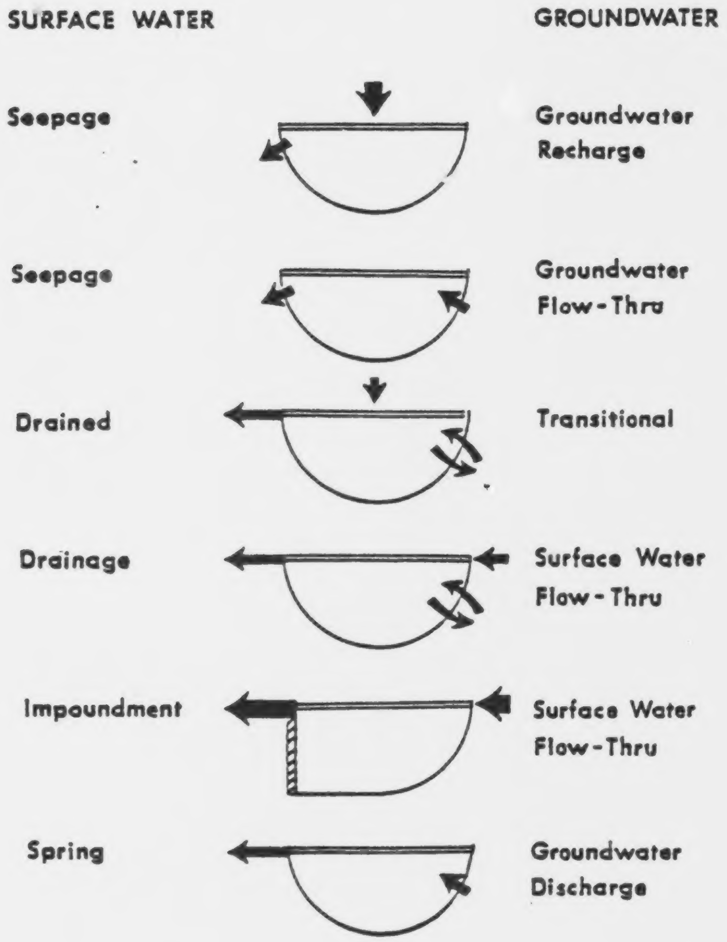

SURFACE WATER
GROUNDWATER
Seepage
Groundwater Recharge
Seepage
Groundwater Flow-Thru
Drained
Transitional
Drainage
Surface Water Flow-Thru
Impoundment
Surface Water Flow-Thru
Spring
Groundwater Discharge

Figure 6. Schematic Description of Hydrologic Classification of Lake Types from Eilers et al., 1983 (27).

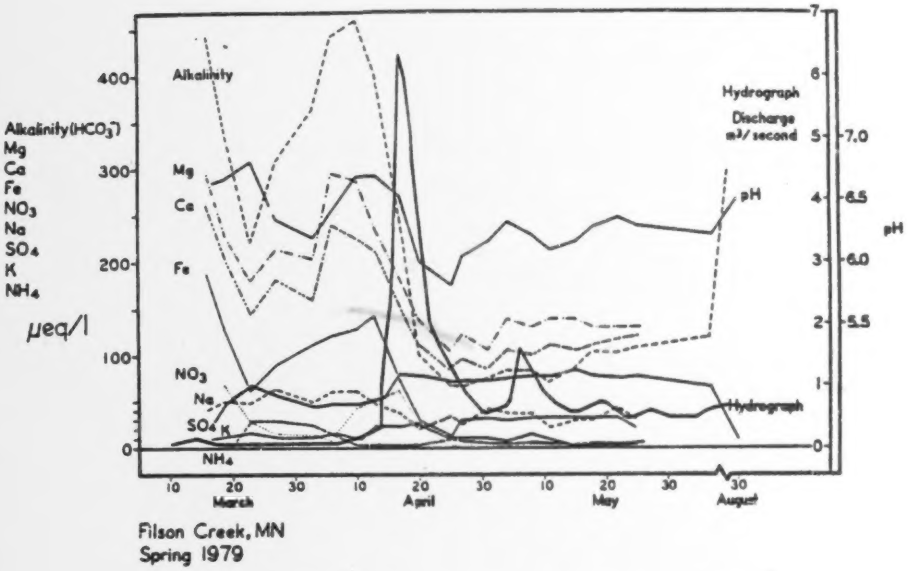
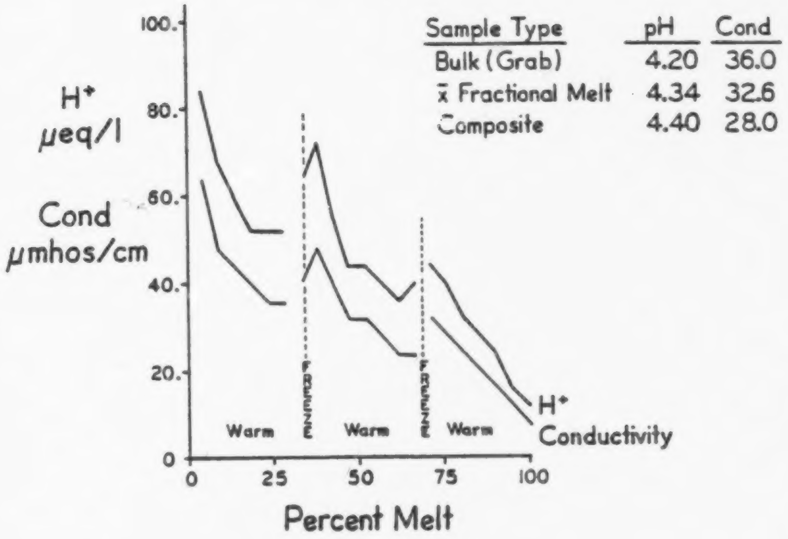


Figure 7. Stream water quality changes during the 1979 snow melt for Filson Creek near the BWCAW of northern Minnesota from Glass and Brydges, 1982, (14).



Sample Type	pH	Cond
Bulk (Grab)	4.20	36.0
$\bar{x}$ Fractional Melt	4.34	32.6
Composite	4.40	28.0

Figure 8. Snow accumulation and snow-melt relationships for H^+ and conductivity, 1980, Taconite Harbor, MN area from Glass and Brydges, 1982 (14).

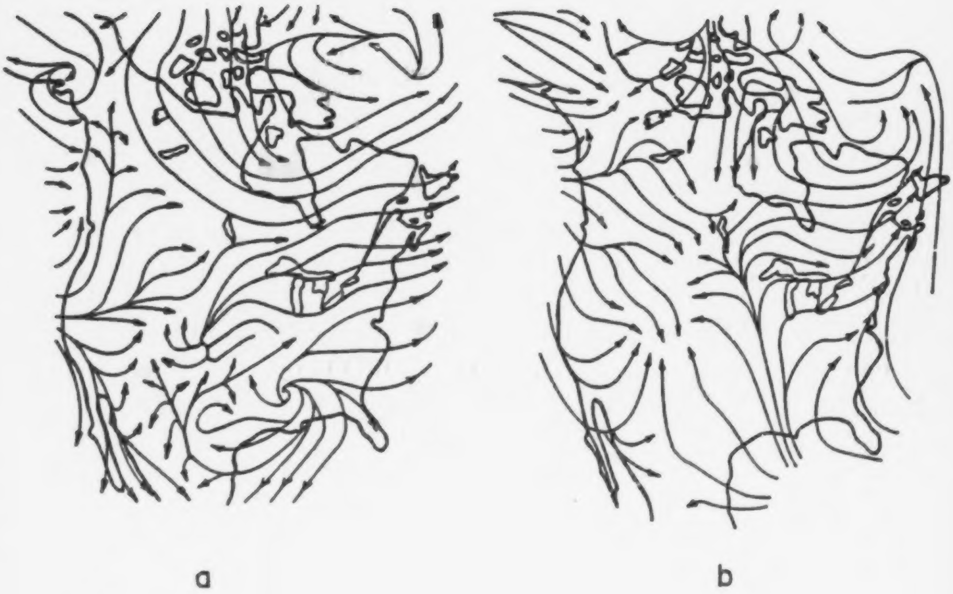
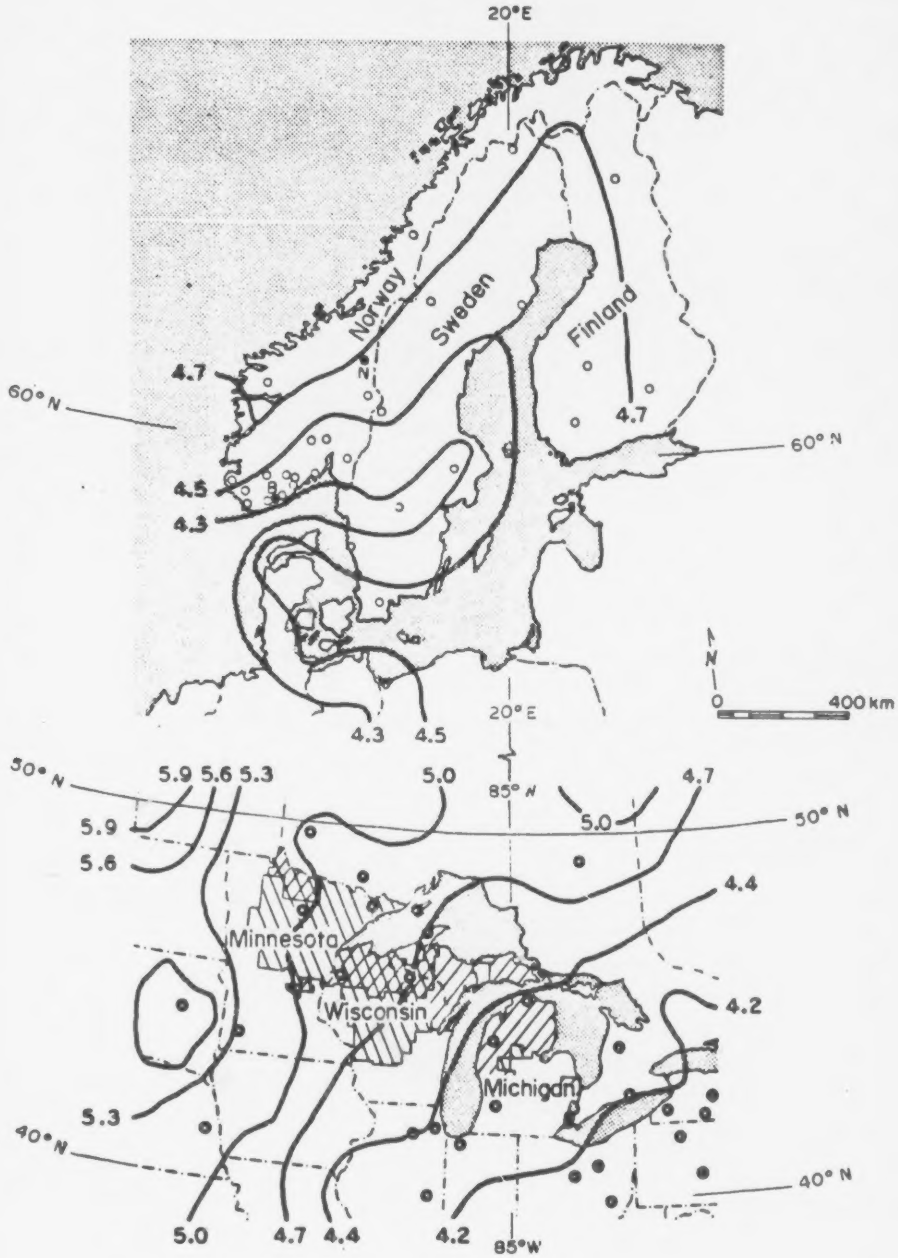


Figure 9. Wind patterns for North America based on surface streamlines for (a) January and (b) July from Glass and Brydges, 1982 (14).

Figure 10. Scandinavian and Lake States regions showing the distributions of sampling stations (first letter of the site names in Table 1) and the volume-weighted average annual pH. Reporting periods differ: Scandinavia, 3 yrs, 1-77 to 12-79 (11,12); Lake States, 2 yrs, 10-79 to 9-81. Areas of high acidity are S. Norway (B - Birkenes) and S.E. Michigan compared with lower acidity in east-central Norway (N - Narbuvollen) and Minnesota. Shading, adapted from Olson et al., 1983, (57), indicates three levels of potential for soils and bedrock to reduce acidity from atmospheric deposition: double-hatching, non-buffering bedrock and soil pH <5.0; hatched down to right, non-buffering bedrock and soil pH >5.0; hatched down to left, buffering bedrock but glaciated soils of pH <5.0 from Glass et al., 1983 (32).


20°E
Norway
Sweden
Finland
4.7
60° N
4.7
60° N
4.5
4.3
N
0
400 km
4.3
4.5
20° E
50° N
5.9
5.6
5.3
5.0
85° W
5.0
4.7
50° N
5.9
5.6
4.4
Minnesota
Wisconsin
4.2
Michigan
5.3
40° N
40° N
5.0
4.7
4.4
4.2
85°W

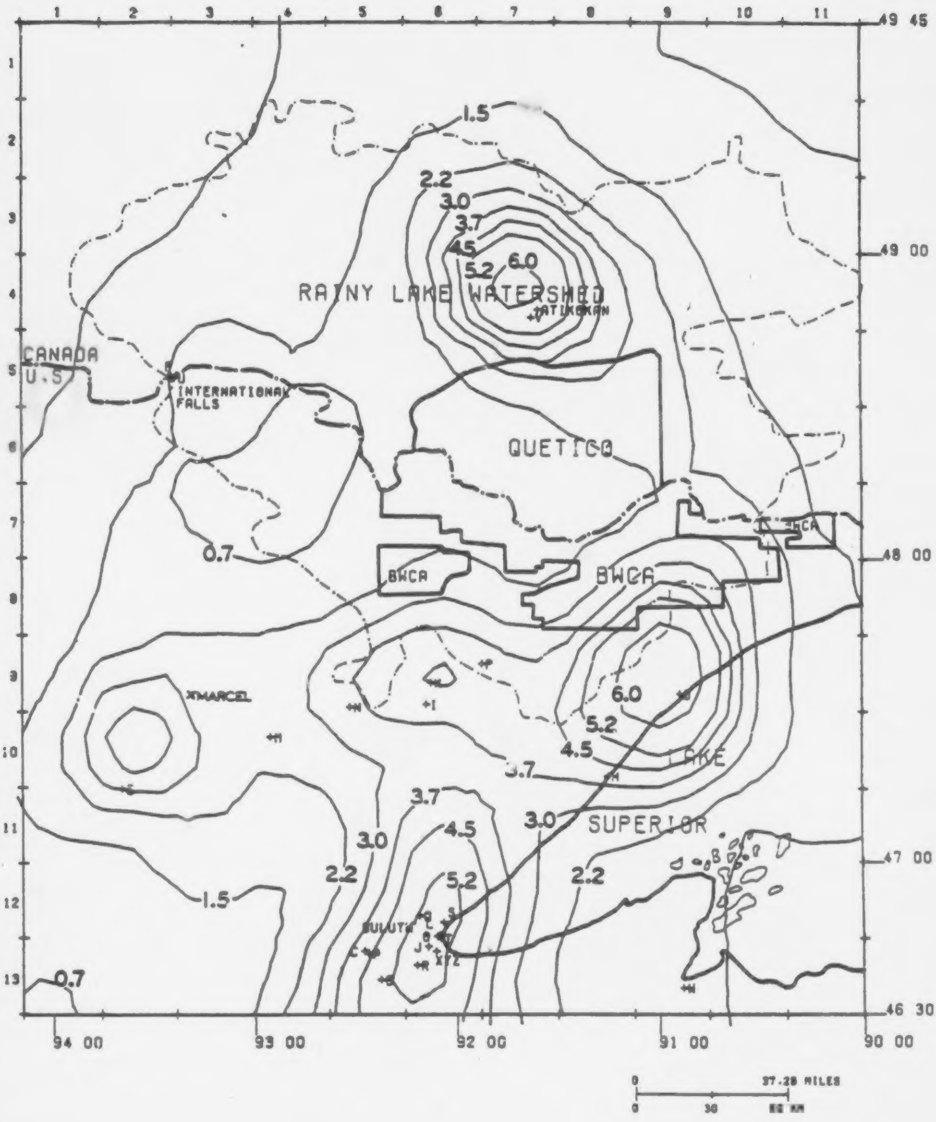

1
2
3
4
5
6
7
8
9
10
11
49 45
49 00
48 00
47 00
46 30
94 00
93 00
92 00
91 00
90 00
1.5
2.2
3.0
3.7
4.5
5.2
6.0
RAINY LAKE WATERSHED
ATIKOKAN
CANADA
U.S.
INTERNATIONAL FALLS
QUETICO
BWCA
BWCA
BWCA
0.7
MARCEL
6.0
5.2
4.5
3.7
LAKE
3.7
4.5
3.0
SUPERIOR
3.0
2.2
5.2
2.2
1.5
DULUTH
0.7
0
37.28 MILES
0
30
60 KM

Figure 11. Calculated deposition of sulfur oxides (wet plus dry as $SO_4^{=}$, kg/ha) for emission sources (1976) within the region shown from Ragland and Wilkening, 1981 (19).

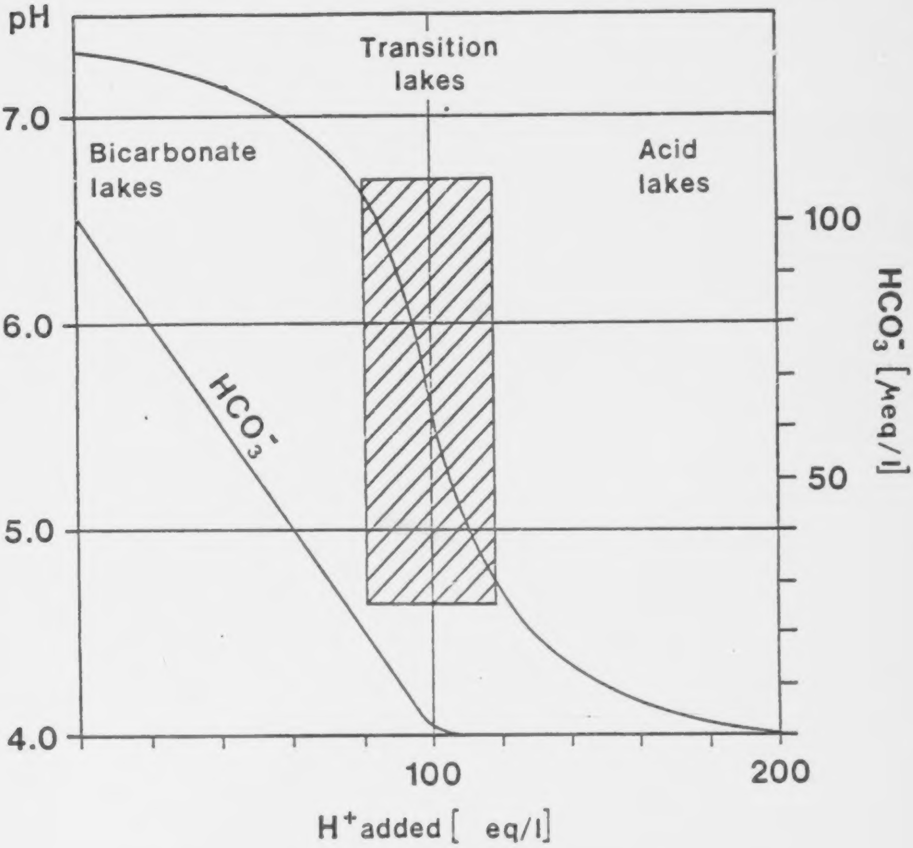


Figure 12. This chart shows the general relationships between pH and acid additions as bicarbonate alkalinity is titrated. The straight line in the lower left represents a laboratory titration, and the curved line represents the apparent "titration" of lakes through acid addition, as reconstructed from large-scale analyses of Norwegian lakes by Henriksen, 1980 (58).

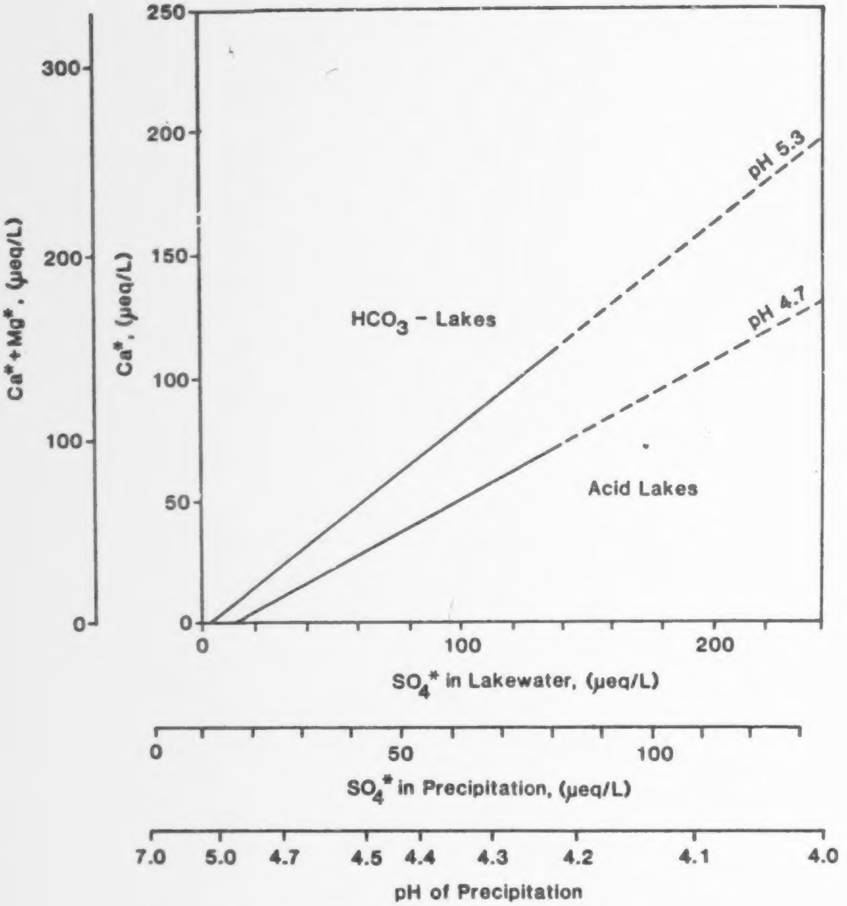


Figure 13. Nomograph to predict the pH of lakes given the sum of nonmarine calcium and magnesium concentrations (or nonmarine calcium concentration only) and the nonmarine sulphate concentrations in lake water (or the weighted-average hydrogen ion concentration in precipitation) from Henriksen, 1982, adapted from MOI 1983 (56,59).

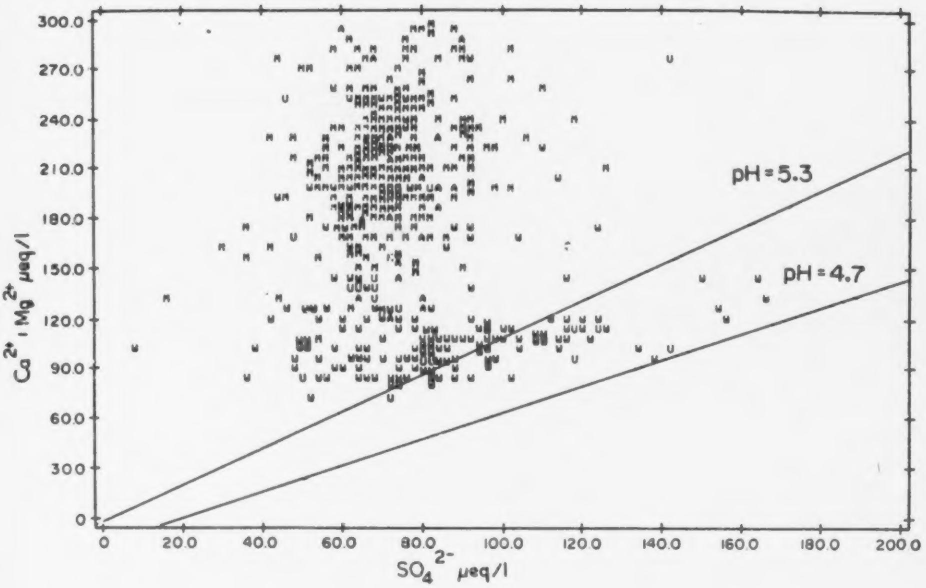


Figure 14. Henriksen type plot of Ca^{++} + Mg^{++} versus $SO_4^{=}$. Lake pH values are indicated.
M = Minnesota; A = Ontario-near Minnesota; W = Wisconsin;
U = Michigan; S = Ontario-near Michigan; all lakes from Brezonik et al., 1984 (45).

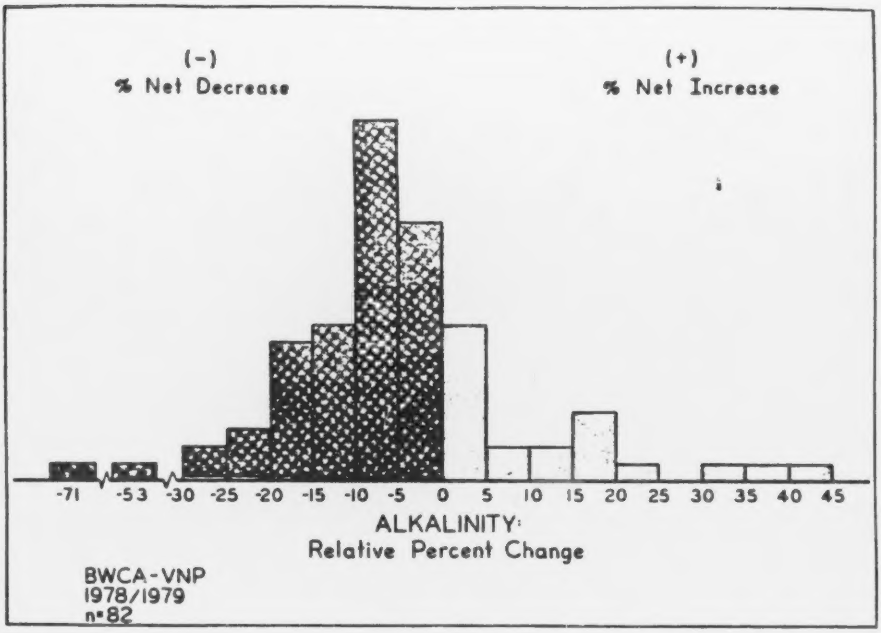


Figure 15. Histogram of relative percent change in lake alkalinity for 82 Minnesota lakes in the BWCAW and VNP comparing fall '78 to spring '79 from Glass et al., 1984 (46).

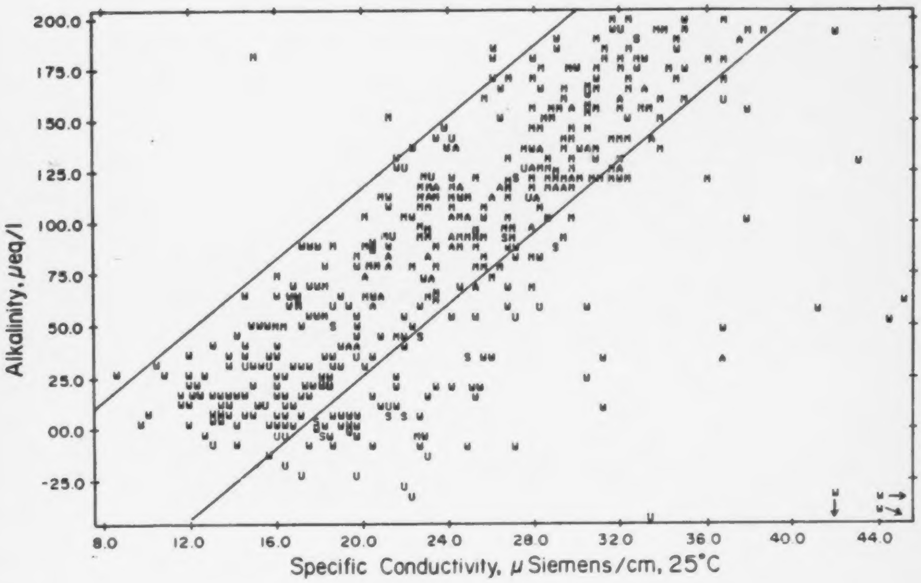


Figure 16. Plot of alkalinity (ueq/l) vs conductivity (uS/cm) for 425 sites coded as follows: M - Minnesota; A - Ontario, near Minnesota; W - Wisconsin; and U - Michigan, upper peninsula; and S - Ontario, near Michigan from Glass et al., 1983 (37).

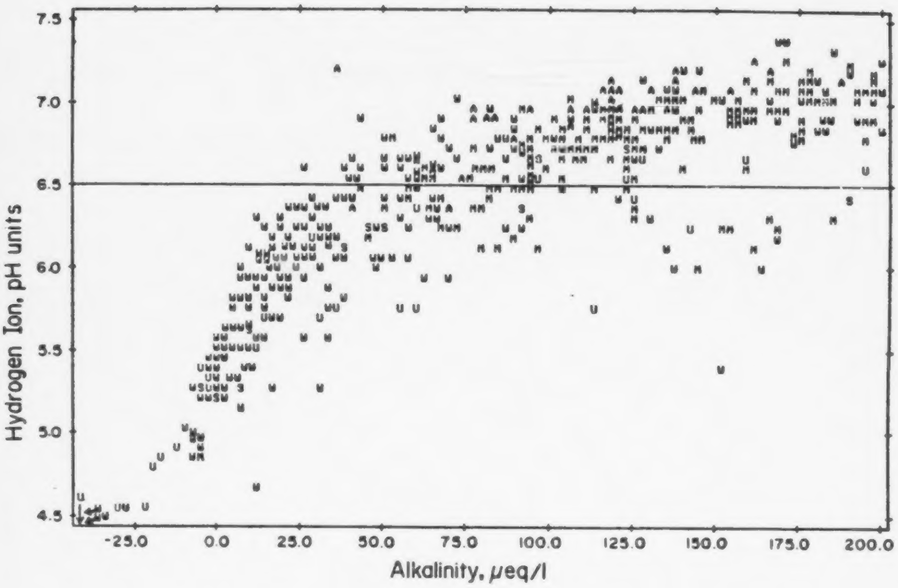
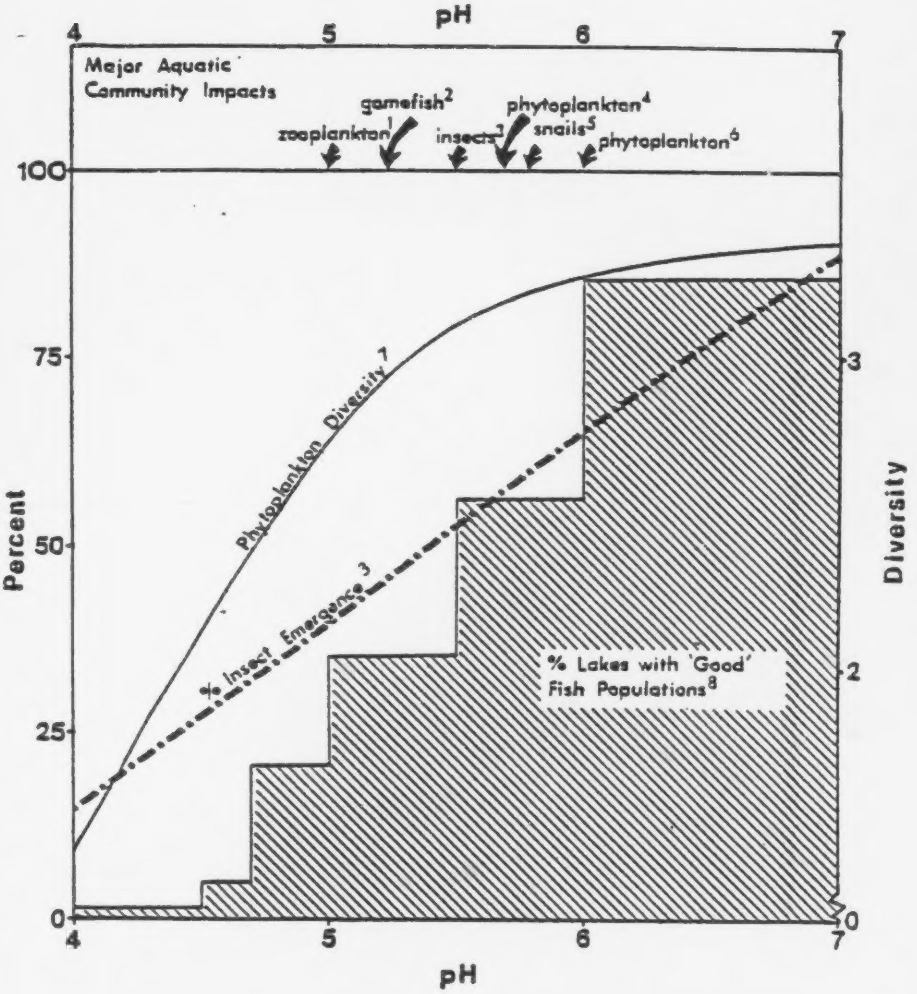


Figure 17. pH/Alkalinity Scattergram for 437 lake and stream sites coded as follows: M - Minnesota; A - Ontario near Minnesota; W - Wisconsin; U - Michigan, upper peninsula; and S - Ontario, near Michigan from Glass et al., 1983 (37).



1 Sprules (1975) - Ontario
2 Beamish (1976) - Ontario
3 Bell (1971) - Laboratory TL_{50}
4 Yan and Stokes (1978) - Ontario
5 Okland (1969) - Scandinavia
6 Wright et al. (1976) - Norway
7 Kwiatkowski and Roff (1976) - Ontario
8 Snekvik (1974) - Norway

Figure 18. Generalized response of aquatic organisms to low pH from Eilers, Berg and Lien, 1983 (33).

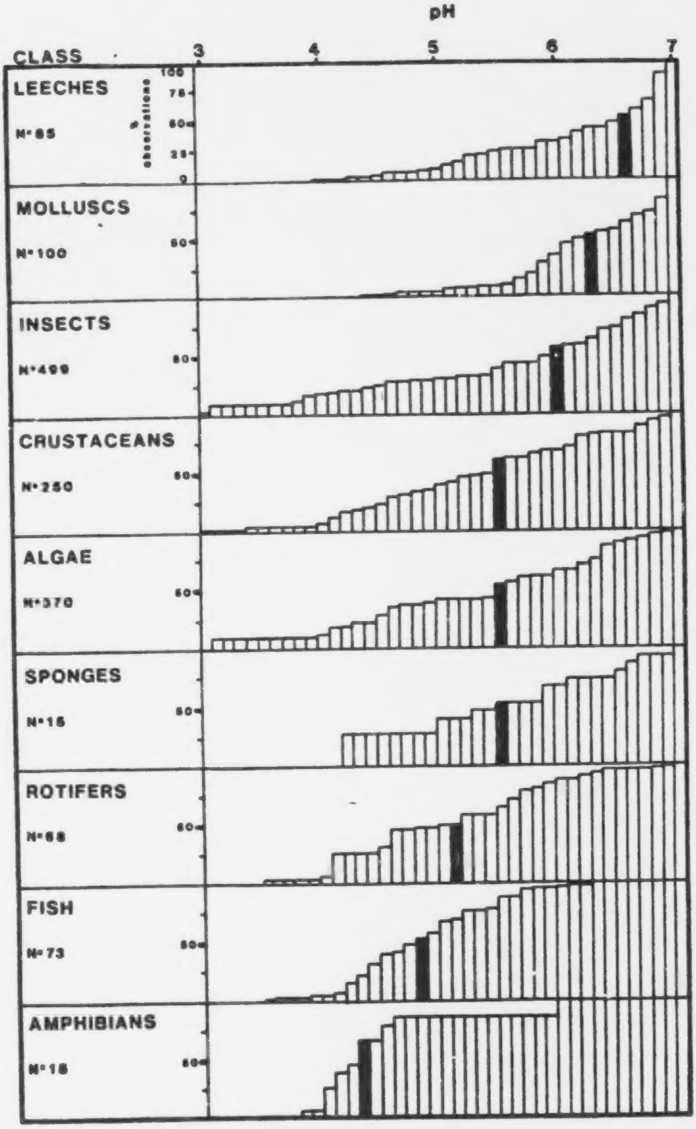


Figure 19. Relative number of taxa of the major taxonomic groups as a function of pH from Eilers, Berg and Lien, 1983 (33).

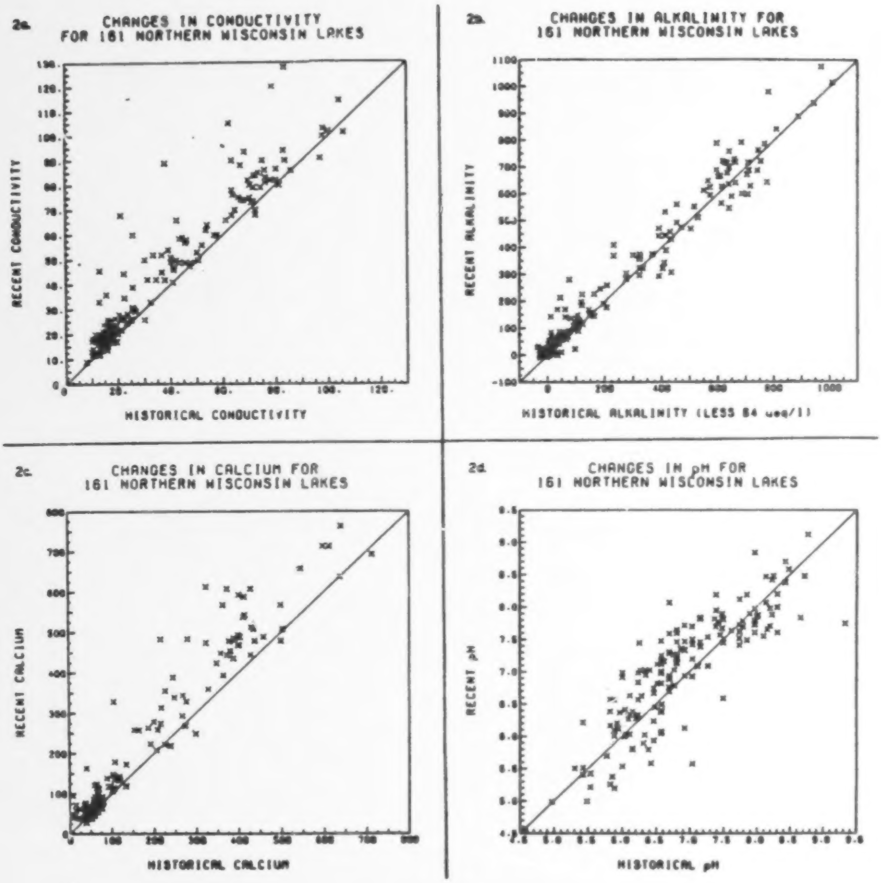


Figure 20. Water quality changes in northern Wisconsin lakes. Historic measurements are adjusted using: a) 20°C to 25° using 2.3%/°C; b) -64 euq/l MOA to TIP; and d) pH = 1.19-1.17 (pH, colorimetric) from Eilers et al., 1984 (34).

Testimony to be presented before the Senate Committee on Environment and Public Works

"The Probable Sources of Pollution Which Give Rise to Acid Deposition in the Upper Midwest, and the Means by Which Such Deposition Could Be Reduced"

by

Dr. Jack D. Shannon
Environmental Research Division
Argonne National Laboratory
Argonne, Illinois 60439

25 August 1983

I am a meteorologist by training, and have concentrated my research efforts during the last ten years on development and application of models of long-range transport and deposition of air pollutants, primarily those related to the problems of acid deposition. The use of current models of transport and deposition in policy analysis and decision making has been and is a contentious matter, and it may be informative to consider the validity of such models. In particular, we might ask how accurate are the models currently available?

Some components of model output, such as atmospheric concentrations of pollutants and rates of pollutant wet deposition, can be compared with observations. The observations necessarily combine the effects of many sources, both anthropogenic and natural, and thus the simulation of the contribution from a single source or region cannot be directly evaluated.

Dry deposition is not currently monitored. To a limited extent it can be indirectly evaluated through monitoring of atmospheric concentrations and characterization of both the receiving properties of the surface and the vertical transfer properties of the atmosphere. The result defines a so-called dry deposition velocity for that type of pollutant to that type of terrain. However, atmospheric concentrations in remote areas are often below the detection limits of most monitoring instruments used to date, therefore making estimates of small amounts of deposition in these circumstances quite uncertain. Moreover, dry deposition velocities for mixed lake and forest terrain have yet to be determined with the most widely-accepted experimental method, the eddy-correlation technique, because of various experimental difficulties. However, in non-arid areas remote from significant sources, wet deposition will probably prove to be the dominant delivery process.

The model developed by myself and my colleagues at Argonne National

Laboratory is called the Advanced Statistical Trajectory Regional Air Pollution Model, or simply "ASTRAP." It simulates regional transport and wet and dry deposition over periods of a month or longer. The model has been applied in various studies for the Environmental Protection Agency, the Department of Energy, the Office of Technology Assessment, state agencies, and electrical utilities. When compared with observations of annual wet deposition of sulfate and nitrate recorded during 1980 by the major sampling networks of the United States and Canada, ASTRAP simulations gave a correlation of about 0.86. In other words, the regional distribution of deposition simulated by the model explained about 75% of the observed deposition variance. While this is quite encouraging, it does not prove that the model is capable of comparable accuracy in simulation of the effect of individual sources or source regions, or over shorter time scales. It might be added that a significant portion of the unexplained variance was probably contributed by uncertainties in the source inventory.

Natural variability of deposition totals, particularly wet deposition, can be quite large, because of changes in precipitation patterns (e.g., wet years vs. dry years), and because of changes in average transport winds. For instance, the month of January 1978 (a year whose meteorology was used in research related to the United States/Canada Memorandum of Intent on Transboundary Air Pollution) was unusually wet in the Northeast and unusually dry in the upper Mississippi Valley. Obviously, resultant patterns of pollutant deposition should have been similarly "abnormal." It follows that, if simulations of transport and deposition are to be used in determination of emission control policy, then it is highly desirable to utilize five to ten years of meteorological data in the simulations.

Models such as ASTRAP quantify perceived relationships between certain pollutant emissions and the deposition of those pollutants in various forms. However, in policy assessment, long-range pollutant transport and deposition is but one set of links in a chain of processes that must be considered in order to estimate costs and benefits of policy options. The atmospheric link must be able to utilize emission scenarios in the form provided (often no better defined than estimated total annual emissions by state, rather than detailed point source data, particularly when the scenario is for some time in the future). Further, the method must produce output deposition estimates in a form that is meaningful in the context of the dose/response functions now being developed by ecologists. If compatible linkages are not developed, no complete assessment is possible. Development of the required, fully-compatible assessment methodologies is underway today; indeed, it is a principal focus of the National Acid Precipitation Assessment Plan.

If one is not constrained to produce a dollar value for both costs and benefits, useful, partial assessments relating the relative costs of control policies to expected changes in pollutant deposition in specified critical areas can be made today. A recent study by Dr. David Streets at Argonne accomplished an assessment of this kind by quantifying various legislative proposals in terms of the annualized cost of the associated emission controls required. With source/receptor calculations from ASTRAP, he then estimated the reduction in deposition expected in the Adirondacks. Street's analysis had previously ranked emissions in each state by potential control costs; this information was then utilized to minimize hypothetical control costs, while still reducing total emissions across a 31-state area by the same amount. This optimization generally reduced overall control costs by a factor of more than two; what is more, deposition in the Adirondacks was reduced even more than it was by the base case of the original legislation as proposed. His final step was to optimize emission control actions to minimize costs, while reducing Adirondacks sulfur deposition only by that amount expected of the legislation as originally proposed. The result was an overall emission reduction total typically of only about one-half of the base case, and an emission reduction cost of about one-fourth of the base case. The difference in annualized cost was between $3 billion and $10 billion per year, depending upon the proposal being analyzed.

I have described this particular assessment study in progress not as an answer to the acid deposition problem, but rather as an illustration of the usefulness of the assessment technique and as an example of the potential financial benefits. Had the deposition reductions been evaluated in other regions, such as the Smoky Mountains or the Boundary Waters Area of present concern, the results would probably have been quite different, depending upon how the optimization of the solution was defined. The optimization for the Adirondacks assessment eliminated emission reductions in the deep South and in Minnesota, since sources in these regions contribute little or nothing to deposition in Upper New York state. On the other hand, these sources have significant effects on the other important receptor areas of concern. Whether or not their absolute contribution to deposition is ecologically significant must be estimated by ecologists. Acidifying deposition to the Boundary Waters Area, or to other sensitive receptor areas of Minnesota and Wisconsin (as shown by actual observations of wet deposition or as indicated by models simulating both wet and dry deposition) appears to occur at a much lower level than in the sensitive areas of the Northeast.

Estimates of the contribution of various sources to sulfur deposition to the Boundary Waters Area, and to the entire states of Minnesota and Wisconsin are given in the following table.

Source Region	Receptor Boundary Waters dry	wet	total	Minnesota dry	wet	total	Wisconsin dry	wet	total
Minnesota	0.37	0.19	0.56	12	6	18	8	4	12
Wisconsin	0.18	0.21	0.39	3	3	6	23	10	33
Iowa				3	2	5	5	4	9
Missouri	0.08	0.18	0.26	2	4	6	4	6	10
Illinois	0.08	0.18	0.26	2	3	5	9	8	17
Michigan	0.06	0.09	0.15	1	1	2	4	3	7
Indiana	0.05	0.12	0.17	1	2	3	4	5	9
Western U.S.	0.25	0.40	0.65	8	10	18	3	10	13
Rest of U.S.	0.05	0.22	0.27	1	5	6	4	6	10
Canada	0.48	0.41	0.89	5	4	9	3	3	6
Total	1.60	2.00	3.60	38	40	78	67	59	126
		kg/S/hectare			kilotonnes S			kilotonnes S	

Here, the Western U.S. is defined as Texas through North Dakota and westward, an area not affected by any of the current legislative proposals. Note that each state contributes more to its own sulfur deposition than does any other single state. The Canadian contribution to deposition in the Boundary Waters Area, about 25% of the total, is greater than the Canadian contribution to statewide deposition because of the border location of the Boundary Waters Area.

The only states in which the total deposition of pollutant sulfur originates more from intrastate sources than from interstate and international sources are (1) the Pacific coast states, which are on the upwind edge of the continent; (2) Arizona and Texas, partly because they are also upwind of eastern sources, and partly because of the large smelter sources located in their southern portions; and (3) Florida, because it is a peninsula. The typical intrastate contribution for states with a significant number of major sources is about one-third of the total; the intrastate contribution for Wisconsin is a bit more than 25%, and that for Minnesota is a bit less. The intrastate share of dry deposition is greater than that for wet deposition, since dry deposition patterns are more source-oriented.

If the pollutant mixture across the continent is radically changed by emission control policies, by the introduction of new technologies, or by other means, it is not certain that the linear approximations of various key chemical transformation and removal processes used in today's models will still hold. While such linearizations can be shown to give good results in simulation of annual deposition patterns now, the validity of their extension to significantly different pollutant emission scenarios is the heart of the "nonlinearity" question, a serious problem for which a series of major field experiments has been proposed. In the interim, current state-of-the-art models are able to provide results for useful, objective assessments.

Michael Gregerson
Northern States Power Company
Testimony Before Senate Committee
on Environment and Public Works
August 25, 1983

My name is Michael Gregerson. I am Director of the Environmental and Regulatory Activities Department for Northern States Power Company and I have agreed to testify before your committee on our system emissions and impacts of proposed SO_2 control programs.

Northern States Power Company and its subsidiaries serve an area of nearly 49,000 square miles in parts of Minnesota, Wisconsin, North and South Dakota and Michigan. The Company generates, transmits, and distributes electric power to nearly 1.2 million customers, serves a population of almost 3 million people, and has total assets of approximately 3.2 billion dollars.

About 43 percent of NSP's electric generation is produced by five major coal plants ranging in size from 275 mw to over 1,400 mw. NSP also operates 1550 megawatts of nuclear generation and has a major purchase agreement with the Manitoba hydro-electric system.

SULFUR DIOXIDE EMISSIONS

The first issue I would like to address is NSP's historical emission rates. In 1970 NSP operated seven coal plants with combined sulfur dioxide emissions of approximately 235,000 tons per year. By 1980, we reduced those emissions to about 105,000 tons per year. In 10 years, emissions from these facilities were cut by two-thirds, a 66 percent reduction. Figure 1 shows the reductions made at each plant. An important fact here is that reductions in sulfur dioxide emissions were not accomplished by decreased use of the older facilities. Figure 2 shows that coal-fired energy production increased over the ten year period while SO_2 emissions decreased. Figures 3 and 4 show 1970 individual plant emission rates, all in excess of 5 lbs/MBtu of heat input to the boiler. For several of the plants emission rates were in excess of 6.0 lbs/MBtu. As Figures 5 and 6 show, by 1980 every facility was at or below 3 lbs/MBtu. NSP's two newest and largest units at Sherburne County operate below 0.7 lbs/MBtu. These major reductions in sulfur dioxide over the entire NSP system result in a system-wide average emission rate of about 1.5 lbs/MBtu. We estimate that these reductions were accomplished at a cost of over 300 million dollars to NSP's rate payers.

CONTROL METHODS

An important question to these proceedings is what type of control alternatives should be used to reduce SO_2 emissions. Every NSP coal-fired power plant burns from 80 to 100 percent low-sulfur Western coal. Sherburne County Units 1 and 2 burn 100 percent low sulfur Western coal and employ flue gas desulfurization systems known as "wet scrubbers." These scrubbers reduce sulfur dioxide concentrations by 60 to 70 percent and particulate concentrations by 99 percent. At NSP's Riverside Plant, Units 6 and 7 have been retrofitted with a new technology known as "dry scrubbing", reducing sulfur dioxide concentrations by 70 to 80 percent. NSP plans to develop an experimental fluidized bed combuster at its Black Dog Plant. This new technology may provide a method of reducing sulfur dioxide that is less expensive than scrubber type systems.

NSP's newest facility, Sherco 3, began construction on August 15. This unit will be NSP's largest coal-fired power plant, employ the latest control technology, and be one of the nation's cleanest plants. Sherco 3 will use a dry scrubbing system and bag house filters to reduce emissions to extremely low levels, and operate at conditions more restrictive than Federal NSPS.

NSP's use of a variety of sulfur dioxide control methods has resulted in substantial reductions in sulfur emissions over the last decade. If I could summarize our efforts to date and concern for the future, it is this: NSP has employed all of the reasonable SO_2 control options available at each of our faciliites. Will we be allowed credit for the major improvements we have made, or be taxed and controlled without regard for these accomplishments.

SENATE ACID RAIN LEGISLATION

Proposed Senate acid rain control legislation calls for a 10 million ton reduction in sulfur dioxide emissions from the 31 states east of or bordering the Mississippi River. Each state's fraction of emission reduction requirements are calculated on the basis of that state's emissions in excess of 1.2 lbs/MBtu. For Minnesota, this results in a required reduction of about 65,000 tons/yr. NSP's fraction of these statewide reductions is approximately 45,000 tons/yr. As mentioned earlier, only scrubbers could be installed to make these reductions. Costs for the scrubbers would be approximately $230 million and result in rate increases over 70 million dollars per year.

HOUSE OF REPRESENTATIVES

Congressmen Waxman and Sikorski also have proposed a form of national acid rain legislation. This bill also requires a reduction in sulfur dioxide emissions of 10 million tons per year from coal-fired power plants. Approximately 63,000 tons/yr in reductions are required for Minnesota. Of this total, NSP estimates approximately a 40,000 ton reduction for the NSP system. Two scrubbers would be required to make such a reduction, and would cost NSP customers approximately 70 million dollars per year. In addition to the emission reduction requirements, the Waxman proposal imposes a 1 mill/KWHr tax on the sale of non-nuclear generated electricity. This tax would cost NSP customers an additional $18.5 million/yr. These funds would be used to pay for scrubbers and other control techniques in the most heavily polluted areas of the midwest. Under the Waxman proposal, NSP customers, who have already paid to clean up the NSP system, would pay again for additional expensive scrubbers and a third time for controls in other parts of the country. These additional costs over and above NSP's existing investment in pollution control would result in increases of $25 to $30 per year for the average residential customer, a seven percent increase.

In both acid rain legislation proposals, no credit is given for past reductions or clean existing facilities. If the costs of control are important, as the clean-up fund suggests, then the costs incurred by NSP's customers for pollutant reductions must be considered. Finally, NSP believes that any funding mechanism must be based upon pollutant emissions. A tax on sales discriminates against utilities that produce substantial energy at low pollutant emission rates. We feel these issues must be addressed in equitable, national acid rain legislation.

CONCLUSION

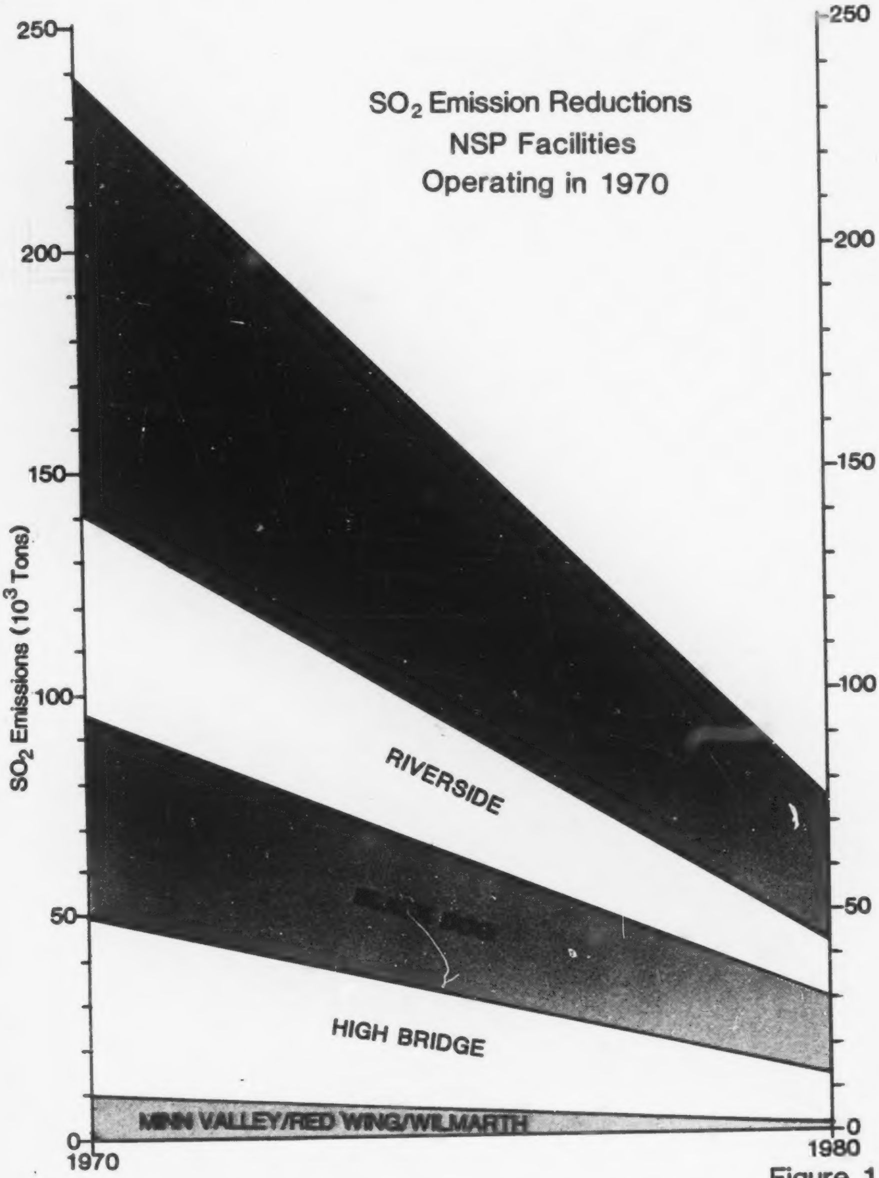
NSP favors acid rain control legislation and supports control of existing sources now. But we also believe that any national legislation must be equitable, must be effective and it must be achievable.

If a national tax is necessary we strongly favor a pollution tax vs a KWHr fee. We also favor a national bill and support control of all pollution sources which affect rain chemistry.

Finally, no bill gives incentives for replacement of older coal-fired power plants with clean, efficient units such as Sherco 3.

We believe that the regulatory framework in Minnesota and the efforts of NSP and other Minnesota utilities over the last 10 years, serve as good examples for national legislation.

Thank you.



SO_2 Emission Reductions
NSP Facilities
Operating in 1970

Figure 1

Historical SO_2 Emissions and Energy Production
from NSP's Coal-fired Generation

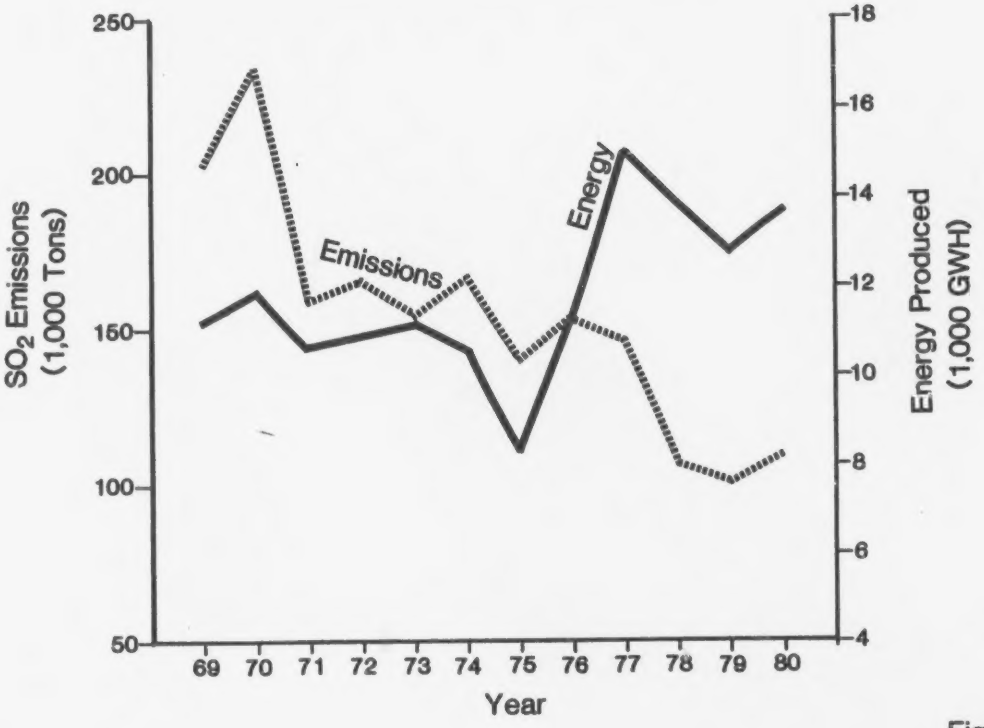
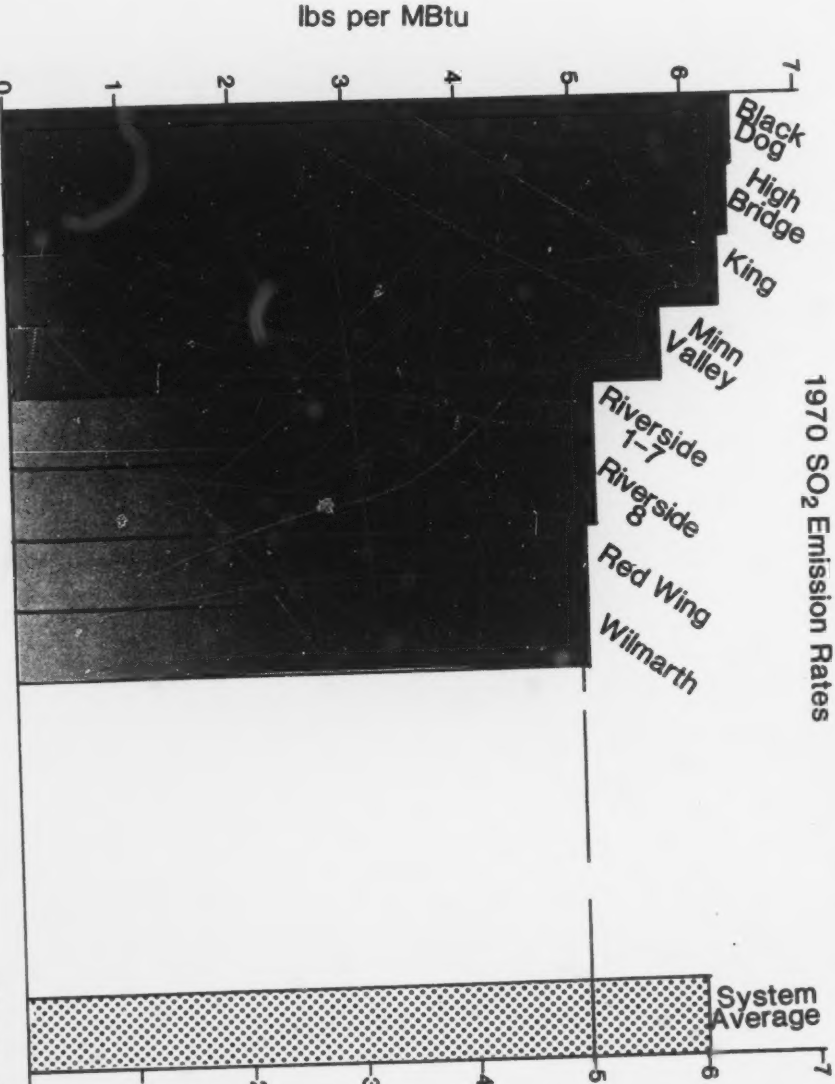


Figure 2



1970 SO$_2$ Emission Rates

Figure 3

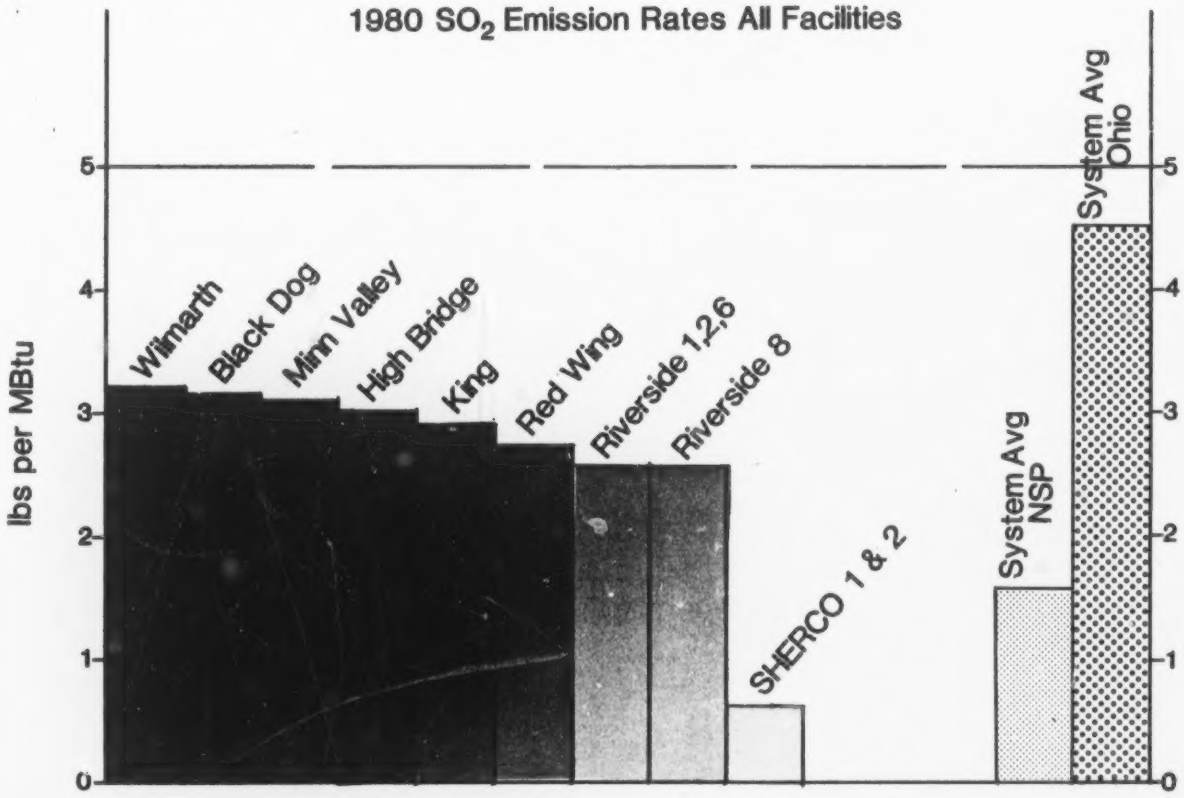
COAL FIRED SYSTEM EMISSION COMPARISON

NSP (1970)

PLANT	RATE	ACTUAL TONS/YR
Black Dog	6.38	44,300
High Bridge	6.34	41,100
King	6.26	97,000
Riverside 1-7	5.14	12,600
Riverside 8	5.14	33,900
MN Valley	5.74	4,240
Red Wing	5.06	1,750
Wilmarth	5.06	1,140

Average Rate	6.01 lbs/MBtu - 21.1 tons/net GWh
Total Tons	236,000
Generation	11,170 GWh

Figure 4


1980 SO_2 Emission Rates All Facilities

COAL FIRED SYSTEM EMISSION COMPARISON

NSP (1980)

Plant	Rate	Actual Tons/Yr	Control
Black Dog	3.17	13,500	80% Low S coal
High Bridge	3.02	15,800	80% Low S coal
King	2.89	32,300	80% Low S coal
Riverside 1, 2, 6	2.58	2,600	80% Low S coal and Dry Scrubber
Riverside 8	2.58	11,200	80% Low S coal
Sherco 1 & 2	0.67	28,500	100% Low S coal and Wet Scrubber
MN Valley	3.11	600	80% Low S coal
Red Wing	2.71	350	80% Low S coal
Wilmarth	3.23	340	80% Low S coal

Average Rate	1.53 lbs/MBtu - 7.71 tons/net GWh
Total Tons	105,200
Generation	13,640

Figure 6

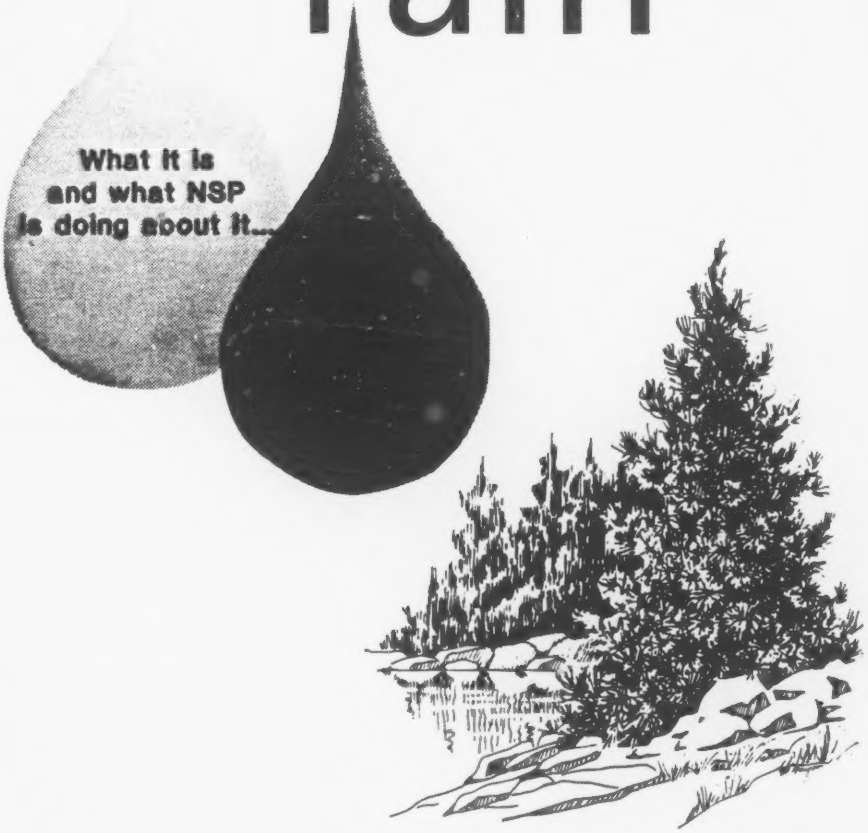
COAL FIRED SYSTEM EMISSION COMPARISON

SUMMARY TABLE

	SO_2 Emissions Tons/Yr	Generation GWHrs Net	Emission Rate Lbs/MBtu	SO_2/Energy Tons/net GWHr
NSP Coal system	105,200	13,600	1.53	7.71
No Carolina plants	406,200	53,138	1.51	7.64
Wisconsin plants	533,700	23,574	4.12	22.64
Large Ohio plants	2,346,800	100,159	4.51	23.43

Figure 7

acid rain



What it is
and what NSP
is doing about it...

FORWARD

Acid rain. You hear and read about it almost daily.

Some say it is the environmental problem of the decade, that it is killing Minnesota lakes, fish, and forests. Some blame industry, especially coal-fired power plants, for the problem and they advocate stern action now to eliminate acid rain.

Others say acid rain is more fiction than fact. They contend more study is needed before laws are passed requiring expensive and needless pollution controls on alleged sources.

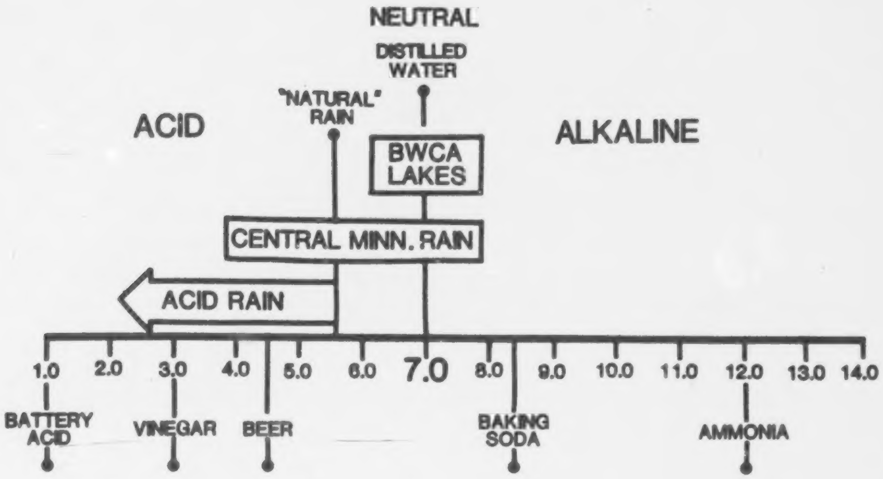
Northern States Power Company (NSP), Minnesota's largest electricity producer, has heard both arguments. Our scientists and policy-makers have considered these viewpoints as well as a great deal of additional information about acid rain, its causes, and effects. In the following pages, we present some of that information, as well as some of our conclusions.

We hope this information enhances your understanding of the acid rain phenomenon in Minnesota. We also hope you learn more about NSP, our policies on acid rain, and our positive approach to the problem.

For more information about this important subject please write to:

Manager, Environmental Sciences
% Northern States Power Company
ERAD
414 Nicollet Mall, Second Floor
Minneapolis, Minnesota 55401

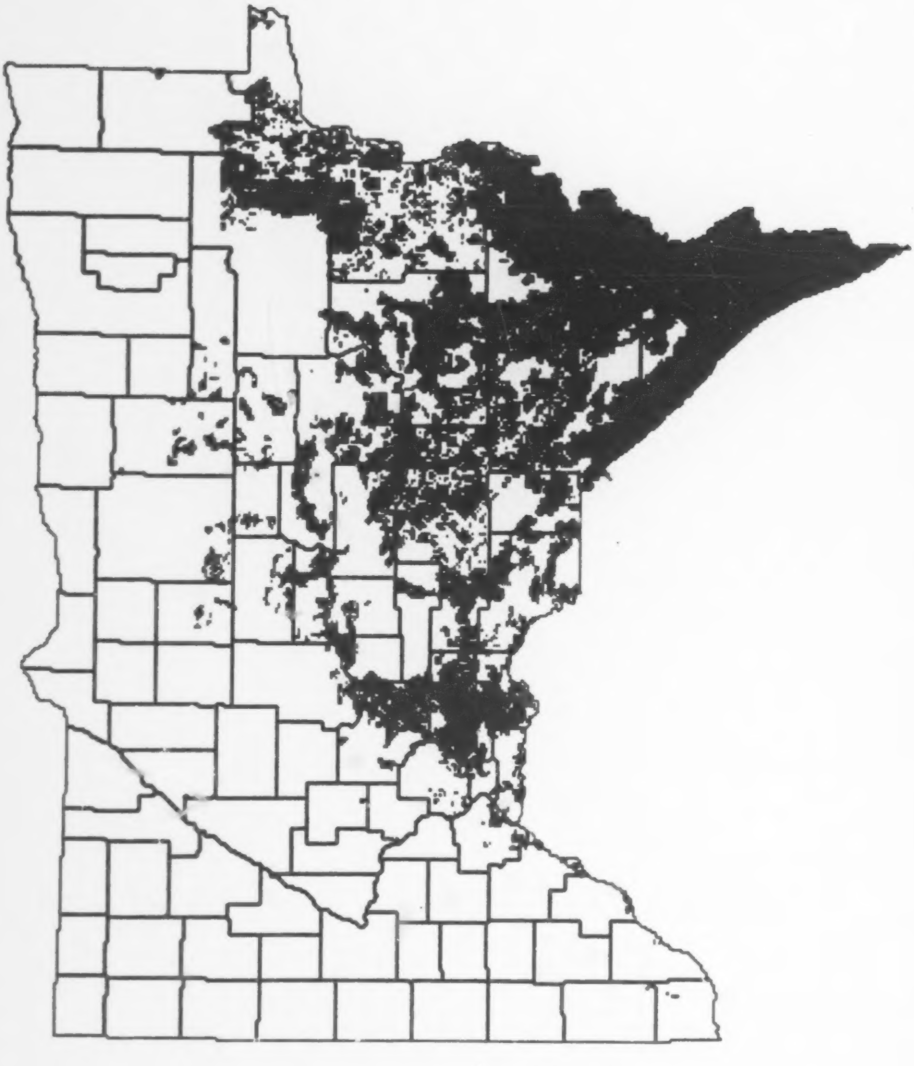
June 15, 1983


NEUTRAL
DISTILLED WATER
"NATURAL" RAIN
ACID
ALKALINE
BWCA LAKES
CENTRAL MINN. RAIN
ACID RAIN
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
BATTERY ACID
VINEGAR
BEER
BAKING SODA
AMMONIA

THE pH SCALE AND ACID RAIN

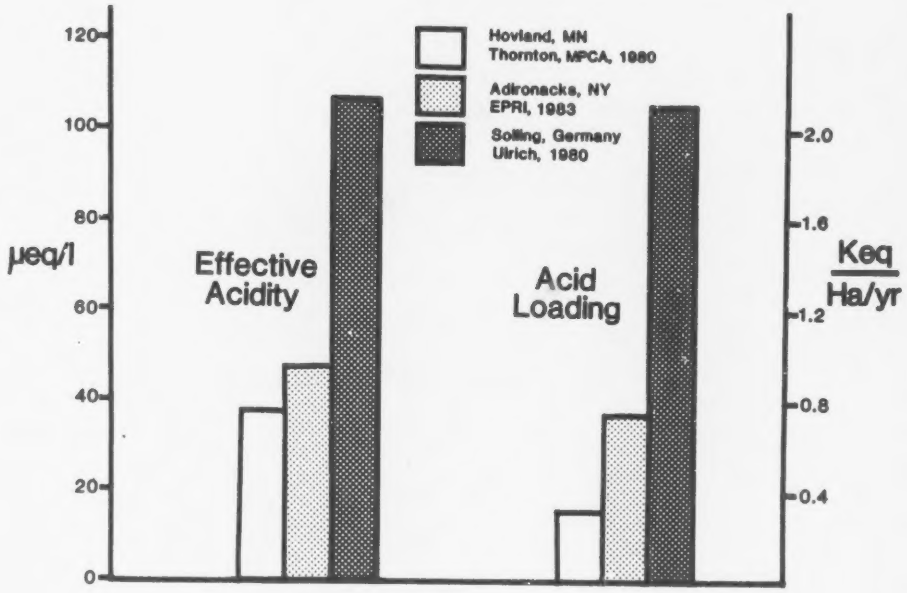
Shown above is a simple graphical representation of the pH scale. Acid rain is popularly defined as any precipitation with pH less than 5.6, caused by the theoretical balance of distilled water and carbon dioxide at atmospheric pressure. But "natural" rain, unpolluted rain, often contains much more than carbon dioxide, a fact which is often ignored. Also shown is the range of rain pH in central Minnesota, collected by the University of Minnesota. NSP is funding more research on the quantity and effects of pollutants in the rain.

The range of pH's for lakes in Minnesota's Boundary Waters Canoe Area (BWCA) is also shown. These data were collected by the USEPA water quality research lab at Duluth, Minnesota. Some lakes in the BWCA have a low capacity to chemically buffer acids.



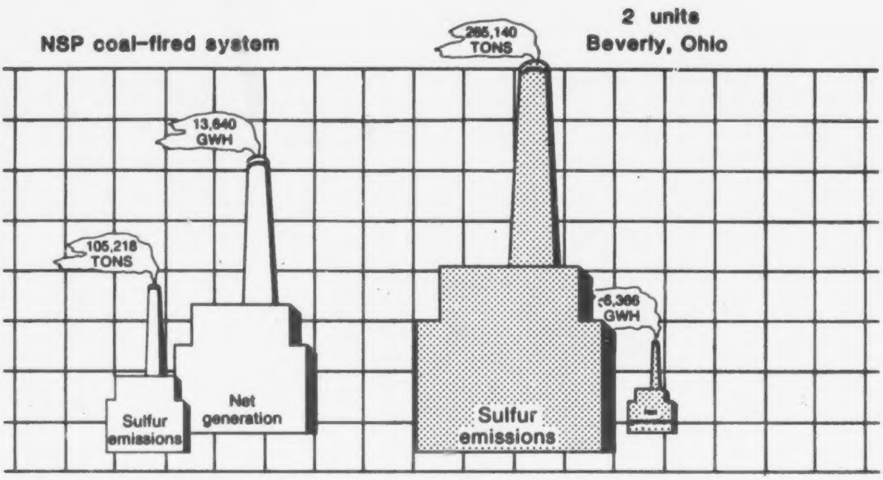
ACID SENSITIVE AREAS OF MINNESOTA

The Minnesota Pollution Control Agency (MPCA) has just completed a detailed analysis in areas which may be "sensitive" to acid rain; susceptible to damage from acid rain. Sensitive areas are shown in black on the figure above; potentially sensitive areas are in gray. MPCA will work to resolve some remaining uncertainties over the next two years. MPCA's work also shows that Minnesota has no "acid or acidified" lakes, and there is no evidence of damage from acid rain.



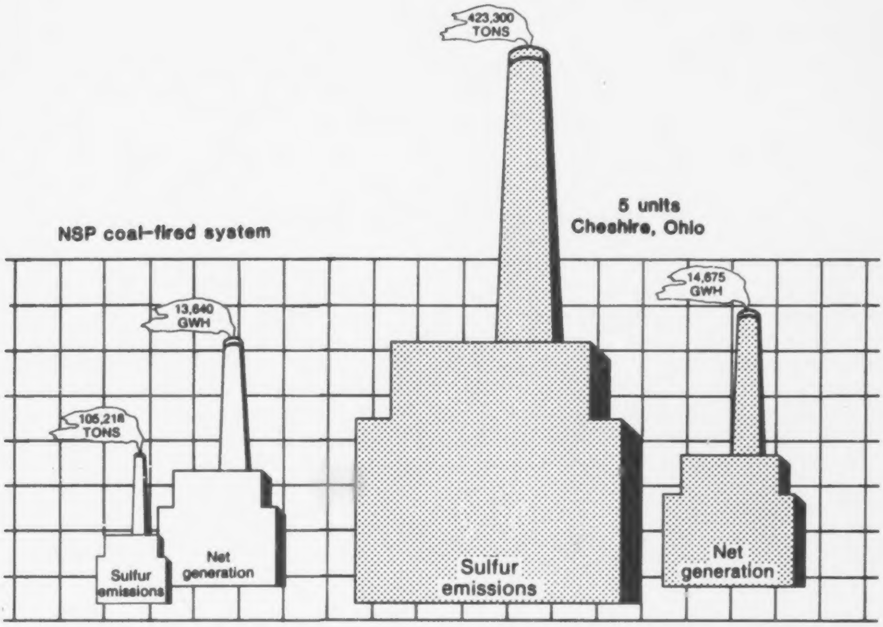
PRECIPITATION AND ACIDITY COMPARISONS

Shown above are comparisons of rain acidity and total acid loading for three areas with sensitive resources. These data are based on the work of Drs. Bloom and Grigal of the University of Minnesota (1983). Acid loading in Minnesota is about one-seventh the level in Germany, and less than one-half that in the Adirondack Mountains. This is important because Minnesota is often described as a sensitive region being damaged by acid rain, as if conditions were just like those of Europe and the Adirondacks. Clearly, conditions are very different.



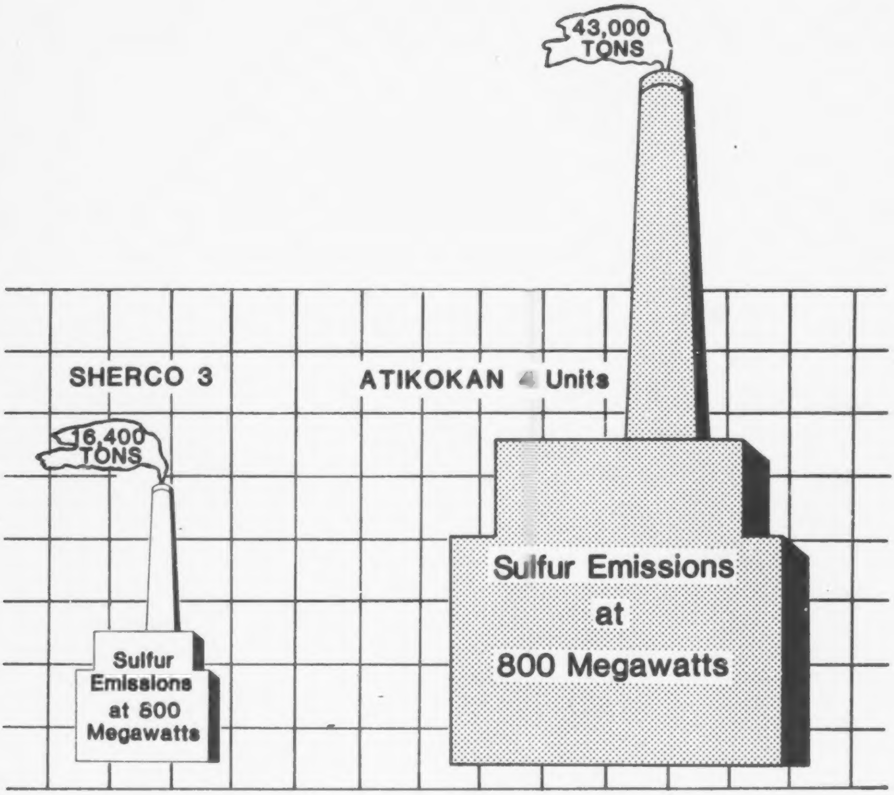
SULFUR DIOXIDE EMISSIONS AND GENERATION COMPARISONS FOR 1980

Shown above is a graphical representation of 1980 SO_2 emissions and net generation. In 1980, a two-unit, coal-fired power plant in Beverly, Ohio produced about 6.4 million megawatt-hours of electricity, and emitted over 265,000 tons of sulfur dioxide. During that same year, the NSP coal-fired system produced almost twice the energy but emitted less than 40 percent of the sulfur dioxide released by the Ohio plant. These great differences are important, and regulations intended to effectively control sulfur dioxide must recognize them.



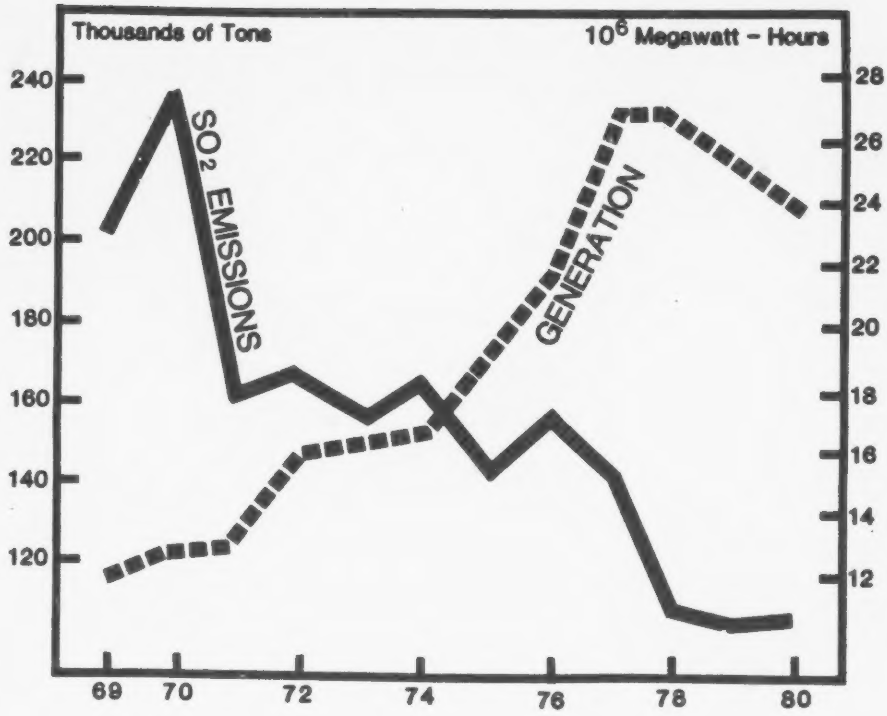
SULFUR DIOXIDE EMISSIONS AND GENERATION COMPARISONS FOR 1980

Shown above is a graphical comparison of sulfur dioxide emissions and energy production. The Ohio coal plant represented here has five coal-fired units, all burning high-sulfur coal. In 1980, those units produced about 14.7 million megawatt-hours of energy and emitted 423,000 tons of sulfur dioxide, averaging over 2.3 million pounds per day. NSP's coal-fired system produced 93 percent of the energy but emitted less than 25 percent of the sulfur dioxide. These large differences in emission rates mean that selective acid rain control strategies must be used if economics and existing pollution controls are properly considered.



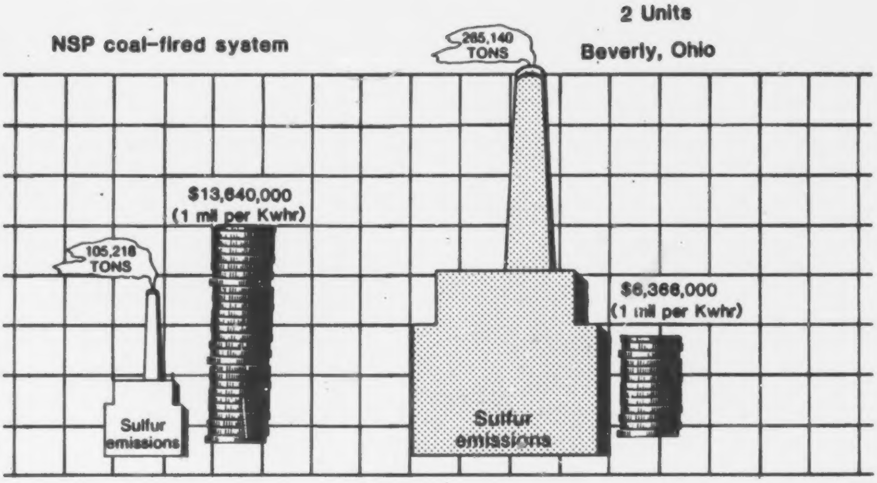
PROJECTED SULFUR DIOXIDE EMISSIONS COMPARISONS

Shown above is a graphical comparison of projected sulfur dioxide emissions from NSP's proposed SHERCO 3 coal plant and the Canadian Atikokan Plant. For this comparison, the proposed capacity of 800 Mw is used for both units. The SHERCO Plant design must meet USEPA's stringent New Source Performance Standards and emission rate control limits. The Canadian government does not impose similar controls on its new facilities.



NSP SULFUR DIOXIDE EMISSION REDUCTION

The NSP coal-fired power plant system produces about 14 million megawatt-hours of electricity each year, with relatively low sulfur dioxide emissions. This is because NSP's sulfur emissions have been reduced by over 60 percent in the last twelve years, by about 140,000 tons of annual emissions. This was accomplished by switching to the maximum amount of low-sulfur coal at every facility, the installation of wet scrubbers on two large units, a smaller retrofit dry scrubber, and a higher proportion of nuclear energy. During this period, the addition of plants with scrubbers and nuclear units has allowed total NSP energy production to double.



SULFUR DIOXIDE EMISSIONS AND GENERATION FEE COMPARISONS FOR 1980

Some national acid rain control strategies call for a one to three mill ($.001) fee imposed on each kilowatt-hour of generation. Shown above is graphical comparison of actual sulfur dioxide emissions and hypothetical generation fees for 1980. If a one mill per kilowatt-hour fee were required, NSP would pay approximately $13.6 million each year, on just its coal-fired generation, using 1980 as a representative year. During that period, the NSP system emitted about 105,000 tons of sulfur dioxide. A two-unit plant in Beverly, Ohio emitted about 265,000 tons in 1980, but produced about half as much energy as the NSP system. If this energy production is representative, generation fees for the Ohio plant would be $6.3 million, also about half.

NSP emitted less than 40 percent of the sulfur dioxide but may pay twice as much to control acid rain. If all generation is assessed, NSP's nuclear capacity would result in fees which are four times higher. These inequities should be addressed in any national acid rain assessment plan.

PROPOSED REGULATIONS

- NATIONAL SCOPE .
  Acid rain regulation must be national in scope. Pollutants or sensitive areas do not know which side of the Mississippi river they are on.

- ECONOMICS AND TECHNICAL FEASIBILITY
  Sulfur dioxide control requirements must consider more than tonnage reductions. Economics, control feasibility, existing pollution controls, and regional differences must be factored into the national plan.

- EMISSION RATE LIMITS
  Emission rate limitations should be promulgated for existing major sources. These limits, expressed in pounds of pollutant per unit of energy, could be individually set in EPA regions, to allow for regional differences. The bubble concept could be applied to system wide averages, allowing operators to choose the most economical reductions. Alternately, the emissions rate limits could be applied to a single facility with multiple units, or even the individual boilers.

- TONNAGE REDUCTIONS
  Major pollutant sources are inventoried by EPA and the Federal Energy Regulatory Commission (FERC). Both emission rates and annual emissions are recorded each year. Reductions in total emissions can easily be determined for any source's emission rate limit.

- OIL AND GAS FIRING
  Oil and gas-fired capacity must be dealt with in these regulations. Many oil-fired facilities have substantial emissions which should not be ignored. Oil switching could be used to avoid sulfur controls, and is contrary to national energy goals.

- RESEARCH
  Research on the acid rain phenomenon, its effects, and control techniques must continue. Research on the benefits of pollution controls and other mitigation methods should also be pursued.

SUMMARY

- MINNESOTA IS DIFFERENT
  Minnesota resources are sensitive, but they are not in imminent danger. Pollutant levels are low, and there is no evidence of damage. All pollutant sources in Minnesota are well controlled, and the MPCA is enacting a state law to protect sensitive resources and further control pollutants as necessary.

- NSP IS DIFFERENT
  NSP's coal-fired power plants *all* have sulfur dioxide controls of varying technology. NSP's rate payers have spent over $300,000,000 on controls to reduce emissions by over 60 percent, more than the 50 percent reduction recommended for controlling acid rain. Equitable acid rain legislation should give some credit for these investments.

- NATIONAL LEGISLATION
  Some of the proposed national acid rain legislation ignores important facts about existing pollution controls, their costs, and other economic matters. These factors must be properly considered in any reasonable regulation strategy.

- LEGISLATIVE ALTERNATIVES
  NSP believes that now is the time for sensible acid rain control legislation. Sensible regulation should consider existing pollution control investments, economics, technical feasibility, and regional differences. Sensible regulation will provide a genuine benefit in proportion to costs which are fairly distributed. NSP is committed to helping develop these regulations.

BEFORE THE U. S. SENATE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

AMENDMENTS TO THE CLEAN AIR ACT

STATEMENT

OF

THE MONTANA POWER COMPANY

BY

EDWARD F. BARTLETT

AUGUST 25, 1983
ROSEVILLE, MINNESOTA

August 25, 1983

STATEMENT
OF
THE MONTANA POWER COMPANY

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I am Edward F. Bartlett, an attorney of The Montana Power Company. I reside in Butte, Montana, headquarters for the Company.

Montana Power is an investor-owned electric and gas utility operating in the western two-thirds of Montana. Our service area consists of about 107,000 square miles. Over 80% of the total population of the state live in our service area.

To serve Montana Power's 232,000 electric customers, the Company owns and operates 13 hydroelectric facilities and five coal-fired thermal electric plants. Montana Power has current total electric capability of about 1,103,750 kilowatts from thermal and hydro sources. The thermal contribution is about 53% of this total capacity.

The Montana Power Company and its wholly owned coal mining subsidiary, Western Energy Company, are deeply concerned about acid deposition legislation now being considered by Congress and the potential negative impact of this legislation on ratepayers served by Montana Power as well as electric consumers served by customers of Western Energy. Acid deposition must be recognized as a problem in specific regions of the United States, particularly in the Northeast. Montana Power supports accelerated research with mitigation and possibly legislative action that will lead to correction of these acid deposition problems. We believe, however, that development of any such legislation should adhere to certain common-sense principles.

Coal-fired power plants in Montana and other Western states are already being required to install technological controls at enormous expense. These controls were imposed despite the relatively lower emission levels in the region due to use of low sulfur fuels and significant use of hydro and nuclear electric generation. Electrical users in the West are already paying for these controls and their operation and maintenance. These costs have been borne by the utilities and their customers; as those costs are likewise borne by sources in other regions which have been required to reduce emissions. We can see no equity in proposals to spread the costs of emission reductions beyond the individual source. We oppose a national fee or tax on utilities, consumers, fuel or other proposals that would shift the financial burden from the sources whose emissions are greater and which directly contribute to the problem.

HR 3400 raises serious questions of equity to Montana's and many other states' ratepayers and utilities in that it imposes a "user fee" on all electric power produced. The costs of pollution control equipment in existing facilities is or will be included in the rates for electric service. In addition to paying these costs, under HR 3400 the consumers would be required to share the financial burdens of paying for scrubbers installed in other states. In essence, our customers and company would pay both for environmental quality in Montana and for reducing emissions in the Midwest. Montana customers would pay $7.7 million yearly if the HR 3400 proposed 1 mill user fee were imposed today. We oppose this legislation as inequitable and illogical

In Montana, we are burning low sulfur coal, as well as employing scrubber technology. A brief survey of the Montana Power coal-fired generating plants reflects that a combination of appropriate technology and the use of relatively low sulfur coal is successful in controlling sulfur dioxide emissions. The emission figures are approximate average emissions assuming operations at full capacity. Our release of sulfur dioxide from Colstrip Units 1 and 2 in eastern Montana averages 0.3 pounds SO_2 per million Btu. These units, as well as the larger Units 3 and 4 which will be in commercial operation in 1984 and 1985, utilize Venturi wet scrubbers for air pollution control. Colstrip Units 3 and 4, which are owned by Montana Power and four other Northwest utilities, will release only 0.07 pounds SO_2 per million Btu. These facilities are well within the federal new source performance standards of 1.2 pounds SO_2 per million Btu. The costs for the air pollution control equipment for Units 3 and 4 is $500 million, which is almost 35% of the total Colstrip 3 and 4 generating plant expenditures.

The attainment of air quality standards has been and will be expensive. We calculate that the cost to customers to cover the fixed charges of our Colstrip 3 and 4 pollution facilities will amount to 11 mills per kilowatt hour, while the loss of energy to operate these facilities will add another 2 mills per kilowatt hour. This environmental cost represents about 25% of the current average retail price our residential consumers pay. It is extremely difficult to envision a scenario in which we or our customers would endorse being assessed to pay for someone else to accomplish what we in the West have accomplished without soliciting contributions.

While we advocate that those primarily responsible for the emissions should pay the primary costs, we believe those costs must be fairly and equitably spread throughout all contributing industrial and mobile sources in the affected area. Further, credit should be given for emission improvements already in place, and costs of reductions by utilities should and must be fully recoverable in rates.

The determination of causes, extent and remedies requires significant research efforts. Regardless of conflicting evidence, unbalanced publicity has resulted in a public perception that acid rain is a serious manmade threat. The foremost need is to obtain the data to resolve the scientific differences of opinion, as quickly as possible, so that rational solutions can be designed and implemented to deal with any real problems that might be confirmed.

One of the disturbing aspects of the acid deposition control measures under consideration is abandonment of the basic principle established in the Clean Air Act Amendments of 1970 that health and welfare are to be adequately protected through scientific consideration of cause and effect. Science, technology, economics, energy and all other relevant factors should not be ignored by placing an arbitrary prohibition on any new emissions.

A cap or rollback on emissions would have long term negative social and economic impacts. The effect of placing a cap on emissions would be commiting our economy to a period of stagnation with no industrial and economic growth.

Montana Power Company believes that a program aimed at controlling acid deposition must be carefully structured to address the regional nature of the problem. Moreover, any remedial action must be reasonably implemented to ensure that control measures produce benefits corresponding to their costs.

Overall costs of reductions in emissions to reduce acid rain are estimated in the billions of dollars. To the extent that controls are phased-in corresponding to research results and to the extent that sources are permitted flexibility in achieving emission reductions, the costs can be minimized. Major initial reductions in sulfur dioxide emissions from coal-fired power plants can be achieved through coal cleaning, fuel blending or voluntary operating restrictions. Sources should be provided the flexibility to decide how best they can meet emission limitations at the lowest possible cost. Federal requirements should not dictate specific technological means, such as scrubbers, for achieving emission reductions.

Any legislation enacted should also encourage the use of new and innovative technologies which offer possible alternatives for the post-1990 period. The addition of new generation methods to the electrical production mix in the 1990s would offer a more effective use of capital over the long run than requiring the addition of costly scrubbers to older plants, particularly when these emerging technologies may produce environmental benefits within 10-12 years that are far in excess of benefits from retrofit scrubbers

In this regard, magnetohydrodynamics (MHD) is one technology which holds out great promise for much cleaner and more efficient burning of coal. While significant research and development remains to be accomplished, a national commitment to the MHD technology in any acid rain control legislation would be a positive contribution by Congress to energy conservation and affirmative environmental action.

Perhaps of even greater significance at this time is the increasing evidence that any emissions reduction program would be of doubtful effectiveness. A recent study of the Energy Laboratory at Massachusetts Institute of Technology concluded that elimination of all sulfur dioxide emissions from all power plants would have very little effect on expected rainfall acidity. One might conclude, from this study, that proposed massive and expensive control programs will not achieve any environmental improvement.

Many studies indicate that local emission sources play a critical role in acid deposition. The most effective solution would seem to be local control of principal emitting sources near identified sensitive areas.

Thank you for the opportunity to present our views.

TESTIMONY OF ELIZABETH P. BARRATT-BROWN
NATURAL RESOURCES DEFENSE COUNCIL
1725 I STREET, N.W.
WASHINGTON, DC 20006

BEFORE THE
SENATE ENVIRONMENT AND PUBLIC WORKS COMMITTEE
MINNESOTA POLLUTION CONTROL AGENCY
1935 WEST COUNTY ROAD B-2
ROSEVILLE, MINNESOTA

August 25, 1983

My name is Elizabeth Barratt-Brown. I am a Resource Specialist with the Natural Resources Defense Council in Washington, D.C. My testimony reflects the views of the Natural Resources Defense Council and the National Clean Air Coalition, of which NRDC is a member.

We regard acid rain as one of the most important environmental problems facing our nation. We believe the time has come to put in place a major emissions control program. Relief must be provided to the areas of our country that have already suffered from acid rain damage and protection afforded to the areas that are vulnerable to future damage.

A full 50% reduction in sulfur dioxide emissions is needed to protect sensitive areas, especially in the eastern states. We call on the Congress to adopt a control program which achieves that 50% reduction. We can burn coal cleanly and for a price less than the cost of annual damage from acid rain. New technologies now being tested hold great promise of reducing these costs even further. We can and we must act this year to set the program in motion.

This morning I would like to limit my testimony to three major points. We believe an acid rain control program should have the following characteristics: a 12 million ton reduction target (50% in the eastern United States); a regional or national reduction area no smaller than the 31 states; and no trade-offs of eastern SO_2 emissions for western SO_2 reductions or NO_x reductions.

Risks to lakes and streams are extensive in the upper Midwest. Together almost 5,000 lakes -- more than half of the total identified as sensitive in the eastern United States -- fall within the upper Midwest. The Congressional Office of Technology Assessment (OTA) estimates that 2,300 (48%) of central and northern Minnesota lakes and 2,470 (42%) of central and northern Wisconsin and Michigan highland lakes are vulnerable to acid rain damage (200 micro-equivalents per liter alkalinity). OTA also estimated that 3,580 miles of stream in the upper Midwest are vulnerable, or one-seventh of the eastern total (200 ueq/l).

Risks to Minnesota conifers may be great. Soil sensitivity maps indicate that Minnesota's poorly buffered glacial soils may suffer adverse leaching of important nutrients and toxic metals such as aluminum. Aluminum, the most prevalent metal in the earth's crust, is readily mobilized by excessive acidity and has been directly linked as a major cause of aquatic damage in acidified lakes. Aluminum is also a highly suspected contributor, in its mobilized form, to the forest damage observed in eastern North America and over extensive areas of West German and eastern European forests.

Risks to crops could also be extensive in Minnesota. A major study of field grown soybeans conducted by Brookhaven National Laboratories indicated that productivity may be reduced by 11% at current deposition levels of pH 4.1. While the western part of Minnesota enjoys less acidic rains, the acidity in the east may pose a substantial economic risk. Every 1% reduction in national soybean productivity means a $50 million loss.

Risks to public health through corroded water supply systems and accumulation of metals in fish are also very real in Minnesota.

Clearly, the upper Midwest, comprised of central and northern Minnesota and Wisconsin and the Michigan highlands, forms an extremely vulnerable area that must be effectively protected in the near term.

We recognize the growing scientific concensus that a 50% reduction in North American sulfur dioxide emissions is necessary to protect the extensive resources at risk. The National Academy of Sciences concluded in 1981 that a 50% reduction in acid deposition is necessary to protect against further damage to aquatic resources (Attachment 1). The Academy warned that at current rates of emissions the number of acidified lakes would double by 1990. The recommendation for a 50% reduction has since been strengthened by the conclusions of the international scientific experts at the 1982 Stockholm Conference on Acidification of the Environment and the Canadian scientific experts' technical reports released last January under the U.S.-Canadian Memorandum of Intent (Attachment 2). The scientific working groups concluded that at a wet sulfate deposition level of 15 to 20 kilograms per hectare per year, deterioration would be significantly slowed. Today most sensitive areas in the East are receiving deposition greater than 15-20 kg/ha/yr, with many areas receiving twice this level. Many scientists argue that a 9 kg/ha/yr level is needed to achieve adequate protection against eventual long-term effects.

The 12 million ton or 50% reduction target would represent a major step toward saving the thousands of lakes and streams at risk in Minnesota, and would provide numerous other important regional benefits. These benefits include lower risks to forests and soils, improved visibility, reduced corrosion of buildings, monuments, drinking water supplies, and better potection agaist human health risks across the eastern United States.

The second point, that the reduction be regional or national in scope and cover the 31 eastern states at a minimum, reflects our concern that the reductions achieve an effective measure of resource protection. Much of the eastern United States and pockets of the West have resources at risk. Both the Office of Technology Assessment and the EPA have identified sensitive aquatic resources in more than two-thirds of the eastern 31 states. The recent EPA Task Force options paper prepared for Administrator Ruckelshaus identifies eight sensitive receptor regions for adverse aquatic effects; the Adirondack lake region; large portions of the New England states and Maritime Provinces of Canada; portions of southern Ontario, Canada; the Smoky Mountain region of Tennessee, North and South Carolina, and Georgia; the Boundary Water Canoe area of Minnesota and the northern lake region of Wisconsin; portions of the Appalachian range in Pennsylvania and West Virginia; the Pine Barrens area of New Jersey; and the Southeastern Central regions with low alkalinities.

I have appended a copy of the EPA national alkalinity map (Attachment 2). It shows the extent of surface waters in the U.S. that have low alkalinities and are most likely to be adversely affected by acid rain. The EPA options paper also identifies other areas of the eastern United States that suffer from regional visibility impairment, other air quality problems, and economically costly materials damage, all of which are strongly influenced by acid rain precursors. Taken together, there are extensive areas at risk across the United States and in Canada. It is our view that a 15- or 21-state control program would fall critically short of protecting these resources.

Another important reason why the reductions should be regional is that the atmospheric picture is extremely complex in this region, with many sources contributing to effects in many receptor areas. The National Academy of Sciences found, in their recent 1983 report, that there is a "thorough mixing" of pollution rom sources within a 600 mile radius and that because of this, every source in the eastern United States should be considered a contributor to the acid rain problem. The idea then that sources in 15 or 21 states can be effectively targeted to protect sensitive receptor areas is flawed. On a regional basis, reductions in emissions would lead to directly proportional regionwide reductions in acid deposition (Attachment 3) If a 50% reduction is made in SO_2 emissions in the eastern region of the United States, a regionwide 50% reduction in acid deposition will result. The Academy report makes it clear, however, that at present we cannot predict that a 50% reduction in 15, 21, or 31 states for that matter, will result in a 50% reduction in Minnesota's acid deposition, but what it does tell us is that the larger the region, the greater the probability will be that deposition will be reduced by 50%. The empirical data in the NAS report supports the conclusion that pound for pound, there is very little difference between the impact of local versus long range sources (Attachment 4). The deposition ratios of sulfur to nitrogen are remarkably even, in contrast to uneven emission ratios nearby.

The question then is where to draw the line. An EPA 21-state program in which the states to the west of the Mississippi are excluded, would not provide important protection for Minnesota against pollution transport from Missouri, which was the fourth largest SO_2 emitter in 1980. On the other hand, a

50-state reduction plan would provide Minnesota with relief from the Plain State tier. A 50-state program would also protect susceptable lakes and streams in the Cascades, the Sierra Nevadas, the Rocky Mountains, and Grand Tetons. Reduction of nitrogen oxides in the Los Angeles basin would reduce the occurrences of extremely high acid fog events that endanger public health and cause significant materials damage.

It is our view, then, that a 31-state control area is a minimum, and that there are very persuasive arguments in favor of a national program.

The final point I wish to make is that the goal of a 50% reduction in eastern sulfur dioxide emissions should not be compromised by reductions in sulfur dioxide in the west or by nitrogen oxide reductions in general. The weight of scientific evidence to date suggests that current levels of sulfur oxides are far too great and must be reduced by 12 million tons in the East or by 50% and that nitrogen oxide emissions be limited. Nitrogen oxides appear to be more readily taken up in the environment. However, if nitrogen oxide growth continues at its current rate, the adverse effects of nitric acids will become an increasingly larger part of the problem. We favor a control program that provides incentives for sources to use technologies which reduce nitrogen oxides as well as sulfur oxide emissions. Possible incentives include special financing opportunities or extended compliance deadlines for using technologies that reduce both pollutants. We oppose a 2 for 1 trade of nitrogen oxide reductions for sulfur dioxide reductions because this would compromise the SO_2 reduction goal.

In finishing, I'd like to commend Senator Durenberger for calling this hearing today, and for his consistent work towards fashioning a solution to the acid rain problem over the last two years. Senator Durenberger is one of the original cosponsors of S.769, the only bill in Congress that would require a 12 million ton reduction. We urge Senator Durenberger to adopt the 12 million ton goal in his forthcoming legislation.

We believe that there is a sturdy scientific base upon which policymakers must build new control programs. We hope the debate over the best program will be brief and conclusive, and we look forward to working with Senator Durenberger in the important months ahead.

NATIONAL
CLEAN AIR
COALITION

THE CASE FOR ACID RAIN CONTROL: Recommendations of Study Panels, 1981-1983

1. **The National Commission on Air Quality: March 1981**

   "Congress should require a significant reduction by 1990 in the current level of sulphur dioxide emissions in the eastern United States."

2. **The National Academy of Sciences: September 1981**

   "It is the Committee's opinion, based on the evidence we have examined, that the picture is disturbing enough to merit prompt tightening of restrictions on atmospheric emissions from fossil fuels and other large sources such as metal smelters and cement manufacture."

   "Of the options presently available only the control of emissions of sulphur and nitrogen oxides can significantly reduce the rate of deterioration of sensitive freshwater ecosystems. In the most seriously affected areas (average precipitation pH of 4.1 to 4.2), this [achiveing a desirable precipitation pH] would mean a reduction of 50 percent in deposited hydrogen ions."

3. **White House Office of Science and Technology Policy panel on acid rain: June 27, 1983**

   "We recommend that additional steps should be taken now which will result in meaningful reductions in the emissions of sulfur compounds into the atmosphere beginning with those steps which are most cost effective in reducing total deposition."

   "If we take the conservative point of view that we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of 'irreversibility.'"

4. **U.S. - Canadian Memorandum of Intent on Transboundary Air Pollution: January 1983**

   Effects Work Group
   (Canadian Summary)

   "Members of the Work Group propose that present deposition of sulphate in precipitation be reduced to less than 20 kg/ha.yr [50% reduction] in order to protect all but the most sensitive aquatic ecosystems."

5. The Stockholm 1982 Conference on Acidification of the Environment: June 1982

Ministers of 21 Countries

"The Conference considered that the establishment and implementation of the concerted programmes for the reduction of sulphur emissions to be a matter of urgency."

"The acidification problem is serious and, even if deposition remains stable, deterioration of soil and water will continue and may increase unless additional control measures are implemented and existing control policies are strengthened."

Scientific Experts

"In sensitive areas with sulphur deposition 0.5g/m^{-2}/yr^{-1} (15 kg/hectare/year sulphate), many surface waters have been acidified."

"In southern Scandinavia and eastern North America the present total sulphur load is above 1.5 g S/m^2/y (45 kg/hectare/year). In these regions, many waters have been acidified - these waters are predicted to improve with a decrease in sulphur loading."

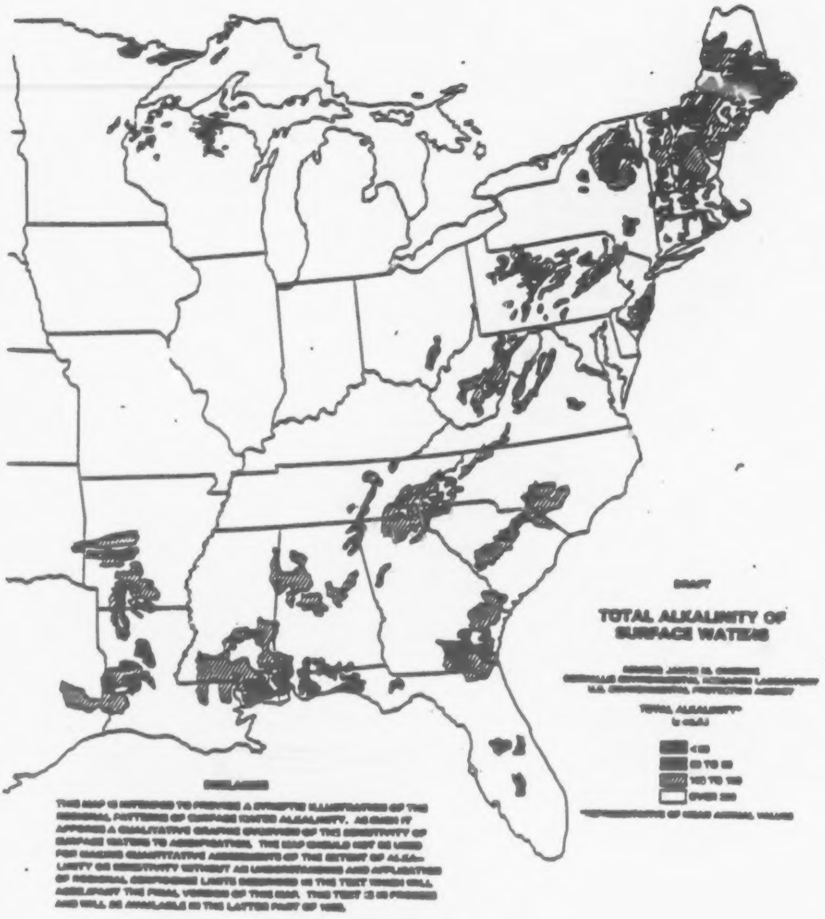

TOTAL ALKALINITY OF SURFACE WATERS

Figure I-1. Total Alkalinity of Surface Waters. (Source: Omernik, 1983).

NATIONAL
CLEAN AIR
COALITION

Conclusions of the National Academy of Sciences Report "Acid Deposition: Atmospheric Processes in Eastern North America"

June 29, 1983

1. Conclusion: **To control acid rain will require a broad eastern-regionwide program of emission reductions:**

   > "Because of the high variability in . . . meteorological phenomena affecting sensitive areas . . . all sources in eastern North America must be considered as contributing in one degree or another to the phenomenon of acid deposition." [p. 5]

2. Conclusion: **While both sulfur and nitrogen oxides contribute to the environmental damage caused by acid deposition, sulfur oxides are the more damaging:**

   > "Nitrogen usually is efficiently metabolized in undisturbed ecosystems, while sulfur frequently is not retained by forest soils. For aquatic ecosystems, therefore, sulfur is more important for acidification than nitrogen. Alkaline as well as acidic cations accompany the movement of sulfate from soils to aquatic ecosystems; consequently, acidification of soil is more likely to occur from excessive sulfate deposition than from excessive nitrate deposition." [p. 19]

3. Conclusion: **It is not possible to distinguish the source of acid rain falling anywhere in the eastern United States:**

   > ". . . it appears that the atmospheric processes in eastern North America lead to a thorough mixing of pollutants, making it difficult to distinguish between effects of distant and local sources." [p. 9]

4. Conclusion: **Reductions in emissions of sulfur oxides within the eastern part of the United States will result in directly proportional reductions in acid deposition:**

   > "If we assume that all other factors, including meteorology, remain unchanged, the annual average concentration of sulfate in precipitation at a given site should be reduced in proportion to a reduction in SO_2 and sulfate transported to that site from a source or region of sources. If ambient concentrations of NO_x, nonmethane hydrocarbons, and basic substances (such as ammonia and calcium carbonate) remain unchanged, a reduction in sulfate deposition will result in at least as great a reduction in the deposition of hydrogen ion." [p. 10]

4a. Conclusion:. **The hypothesis that reductions in sulfur oxides emissions will result in less than proportional ("nonlinear") reductions in acid deposition is not supported by the evidence. (This argument is based on the idea that there may already be more sulfur in the atmosphere than oxidants available to convert it to acid-forming compounds.)**

> "However, on the basis of analysis of currently available data in eastern North America and within the limits of uncertainty associated with errors in the data and in estimating emissions, we conclude that there is no evidence for a strong nonlinearity in the relationships between long-term average emissions and deposition." [pp. 7, 139]
>
> "The evidence based on empirical observations appears incompatible with a seriously nonlinear system in terms of our current knowledge." [p. 138]

5. Conclusion: **Selective, or "targetted," emission reduction as a means to reduce acid precipitation in critically affected areas, is not a viable control strategy:**

> ". . . current models have not provided results that give confidence in their ability to translate SO_2 emissions from specific sources or localized groupings of sources to specific sensitive receptors." [p. 83]
>
> "The North American data therefore suggest that (a) whatever atmospheric processes are taking place, pollutants are being thoroughly mixed over a region with linear dimensions up to 1,000 km. . . ." [p. 9]
>
> "An important feature of the long-range transport of air pollutants is that the plumes from individual sources may become so dilute and so thoroughly mixed far downwind of major source areas that the attribution of specific parcels of polluted air to specific sources is impractical." [p. 35]

6. Conclusion: **Long distance transport is a major cause of acid precipitation:**

> "Analyses of the trajectories of precipitating systems of delivering acidic precipitation to Whiteface Mountain and Ithaca in New York and south central Ontario in Canada indicate that most of the acidity in precipitation at these sites -- as well as most of the precipitation -- is associated with air masses that have passed over source regions to the south and southwest." [p. 140]

National Academy of Sciences
June, 1983

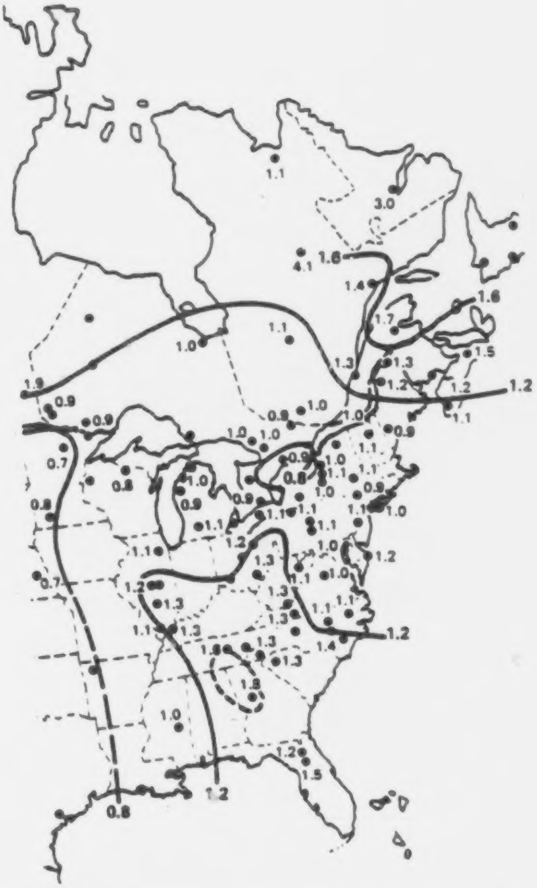

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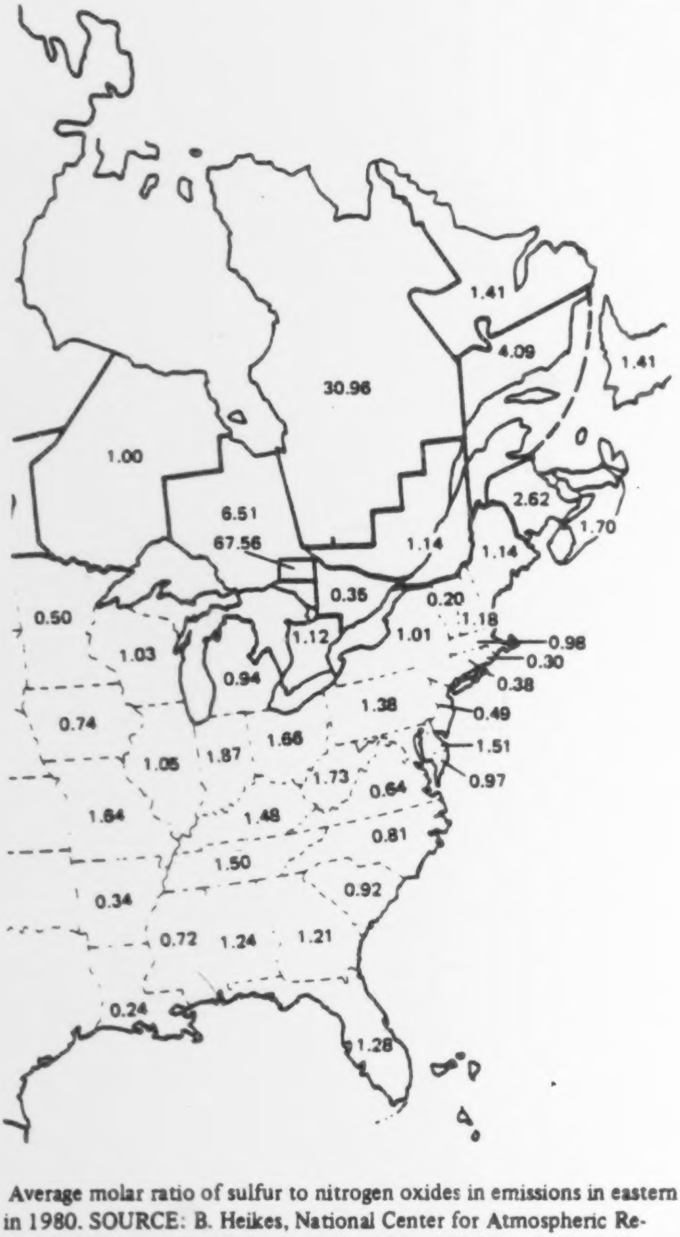
FIGURE 4.17 Average molar ratio of sulfate to nitrate in precipitation in eastern North America in 1980. SOURCE: B. Heikes, National Center for Atmospheric Research, personal communication (1983). Based on data from U.S./Canada Work Group #2 (1982).


1.41
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1.41
30.96
1.00
6.51
67.56
2.62
1.70
1.14
1.14
0.35
0.20
1.18
1.12
1.01
0.98
0.30
0.50
1.03
0.94
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1.66
1.51
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1.87
1.73
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0.64
1.64
1.48
0.81
1.50
0.92
0.34
0.72
1.24
1.21
0.24
1.28

FIGURE 4.18 Average molar ratio of sulfur to nitrogen oxides in emissions in eastern North America in 1980. SOURCE: B. Heikes, National Center for Atmospheric Research, personal communication (1983). Based on data from U.S./Canada Work Group #3B (1982).

ACID RAIN: 1983

FRIDAY, OCTOBER 14, 1983

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Concord, N.H.

The committee met at 10 a.m., in rooms 210 and 211, Legislative Office Building, Concord, N.H., Hon. Gordon J. Humphrey presiding.

OPENING STATEMENT OF HON. GORDON J. HUMPHREY, U.S. SENATOR FROM THE STATE OF NEW HAMPSHIRE

Senator HUMPHREY. Good morning and welcome. The hearing is on behalf of the Senate Committee on Environment and Public Works. Although previous hearings on the subject of acid rain have been held in our neighboring States of Vermont and Maine, this is the first hearing of the committee in New Hampshire. It is being held at my request.

Since the hearing is being held in New Hampshire, we will spend considerable time discussing New Hampshire's aspects of acid rain. But this is more than merely a hearing to discuss New Hampshire, as important as that may be to us. Some of today's witnesses enjoy national and international reputations as experts on acid rain.

We would like to hear what they have to say especially with regard to the threat that acid rain poses for New Hampshire's forest and soils as well as her lakes and streams.

Acid rain is the product of sulfur and nitrogen pollutants which pervade the North American environment. It can and does acidify lakes and streams and rivers. It can and does strip soil of essential nutrients such as calcium, magnesium, and releases toxic metals such as mercury and aluminum.

In some regions of the United States, including our own, four out of every five lakes and streams are vulnerable to acid rain. One out of every three lakes and streams is already acid altered in these regions, and this includes our State. Hundreds of lakes in the Adirondack region are showing signs of acid stress; many are already dead. Many other regions of the United States, beside our own area, are also vulnerable to acid rain. These include Pennsylvania, West Virginia, northern Minnesota, Wisconsin, Michigan, parts of southern Appalachia, and North and South Carolina, Florida, large parts of Washington State, Oregon, Idaho, and California.

Simulated acid rain applied in field experiments has been shown to cause crop losses. It is suspected of causing tree and forest losses as well, and both of these matters are of great concern to us in New Hampshire.

Acid rain corrodes metal and erodes other building materials. The best estimates of the United States sets losses due to acid rain at $5 billion each year.

During the past 4 years, the Committee on Environment and Public Works has conducted 11 days of hearings, heard from hundreds of witnesses and interested parties, and accumulated thousands of pages of testimony on the subject of acid rain. However, as I said earlier, this is the first undertaking in New Hampshire.

The hearing will mark the beginning of the committee's efforts to produce a strong and workable acid rain control program which can be adopted by the Senate and become law.

I will discuss the hearing schedule with Senator Stafford of Vermont who chairs the committee, he and I agreed that the time is now to report a bill and to get it passed by the Senate.

As far as I'm concerned, we know what the problem is. We also know what the solution is. What has been lacking is not knowledge but political will to confront the issue squarely. As one Senator, I intend to do all that I can to see that we will have not just a bill but a law and a statute.

Our first panel of witnesses is comprised of Dr. James Hornbeck, research forester, Hubbard Brook Experimental Station in West Thornton, N.H.; Dr. Richard Klein, Department of Botany, University of Vermont in Burlington; Dr. George Tomlinson, Domtar Research Center, Sennerville, Quebec; and Dr. Kenneth Kimball, Appalachian Mountain Club in Gorham.

Good morning. We will begin with Dr. Hornbeck.

May I say this to this panel and all of the witnesses that, given the number of witnesses, we will ask that you summarize your testimony, if possible. Of course your full statements will be included in the record.

STATEMENT OF DR. JAMES HORNBECK, RESEARCH FORESTER, HUBBARD BROOK EXPERIMENTAL FOREST

Dr. HORNBECK. Mr. Chairman and members of the committee: The Forest Service appreciates the opportunity to appear before the committee today to describe research on acid precipitation at the Hubbard Brook Experimental Forest.

The Hubbard Brook Experimental Forest was set aside by the U.S. Forest Service in 1955 for conducting research on hydrologic, nutrient, and energy cycles of forest ecosystems. In the ensuing years, hundreds of scientists, both national and international, have conducted research at Hubbard Brook. The forest and aquatic ecosystems at Hubbard Brook and nearby areas have been as intensively studied, and have become as well understood as any in the world. The wealth of background data that has accumulated is now playing an important role in the acid rain problem. We would like to describe just a few of the studies carried out under the Hubbard Brook project, and show how they contribute to understanding of acid rain.

The first category is precipitation chemistry. Precipitation chemistry has been monitored routinely at Hubbard Brook since 1963, providing the longest continuous record of any location in North America, and perhaps the world. Such a record is invaluable. For example, when the European nations began describing their concerns about acid precipitation in the late 1960's, we were able to quickly look at the Hubbard Brook record and determine that Northeastern United States was experiencing similar situations. Without the Hubbard Brook data base, recognition of acid rain and initiatives for studying sources and effects could have been delayed for several years.

The long-term record has allowed us to look for trends. We know precipitation at Hubbard Brook has been acidic since the start of data collection in 1963, having an average annual pH of 4.1. There have been short-term ups and downs, but from 1963 to 1982 there has not been any significant change in the pH of precipitation. However, the sulfate ion, which is a major constituent of acid rain, has declined by 20 to 30 percent since 1963. Most of this decline has occurred since 1972, and corresponds to a national reduction in emissions of sulfur dioxide. This unique finding, available only because of the long-term data collected at Hubbard Brook, played a key role in the recent National Academy of Science recommendations addressing the acid rain problem.

Individual storms have also been studied at Hubbard Brook, and have helped to establish the source regions for acid rain. Storms that come to Hubbard Brook from the relatively uninhabited areas of Maine, Quebec, and the Maritimes are low in acidity and ions and serve as baseline for clean precipitation. On the other hand storms that originate in the industrial midwest and mid-Atlantic States have 8 to 10 times greater concentrations of hydrogen and sulfate ions. This same study shows that storms that originate over the Atlantic and track across Boston or southern New England before arriving at Hubbard Brook are equally acidic. This suggests that emission sources close to home, as well as those more distant must be addressed.

The second category is soil acidification. Formation of forest soils in New England, and especially in areas like Hubbard Brook, is an acid-forming process. In recent years controversy has arisen as to whether acid rain may accelerate this process. If it does, important soil nutrients could be lost and aluminium could become available to the extent that it might be toxic to trees and fish. As part of Hubbard Brook research we have been studying the ability of soils to counteract or buffer acid rain. Our data suggest that forest soils may not be the super buffer that is sometimes depicted. Evidence suggests that in a worst-case situation, acid rain could cause soil pH in New Hampshire to become more acid by one pH unit in as short a time as 35 to 40 years.

Another category of our research is combined effects with harvesting. Some human effects such as forest harvest could conceivably compound the effects of acid rain. Studies at Hubbard Brook show that the forest canopy lessens the acidity of precipitation by exchanging nutrient ions such as calcium and potassium for hydrogen ions. What might happen if the canopy is removed and precipitation is allowed to fall chemically unchanged on the forest soils and streams? We are addressing this question as part of a newly initiated study on an experimental watershed at Hubbard Brook. All trees are being harvested from the watershed which will be intensively studied for the next few years.

The final category is aquatic systems. The long-term record shows how streams respond to acid precipitation. Presently the streams originating near the tops of watersheds at Hubbard Brook are nearly as acid as incoming precipitation. As these streams flow downward and increase in size, they tend to lose much of their aciditiy. Studies have been conducted to see what might happen if the downstream sections remained acidic. A small stream that normally has a pH of 6 was artificially adjusted to pH 4 by adding sulfuric acid. The acidification had marked impact on aquatic organisms, eliminating some species and tending to decrease the complexity of the food web—a highly undesirable effect.

A major concern about acid rain is how it affects ponds and lakes. Using the Hubbard Brook data base and facilities we have been studying six remote ponds within the White Mountain National Forest. These ponds have seemingly similar watershed characteristics and precipitation chemistry but vary widely in their chemical composition. Our results suggest that Cone Pond, which is widely recognized as one of the most acidic ponds in New England, probably has acidic inputs from material in the surrounding watershed that far exceed those in precipitation. Some data imply that Cone Pond has been highly acidic for hundreds of years. In contrast, nearby Black Pond has physical and chemical characteristics which produce enough alkaline or buffering substances to make it doubtful that acid rain could ever have much of an impact. Such findings help to predict how ponds will respond to future changes in chemical content of precipitation.

In conclusion, the unique knowledge obtained at the Hubbard Brook Experimental Forest through efforts of many scientists has proven extremely valuable in defining and evaluating the acid rain problem. The resources and accumulated information, recently referred to in a newspaper article as "A National Treasure," insure that Hubbard Brook will continue to be in the forefront of the search for solutions to the acid rain problem.

Mr. Chairman, thank you for the opportunity to appear here today. This concludes our prepared statement. We would be happy to answer your questions.

Senator HUMPHREY. Thank you, Dr. Hornbeck. I think the best way to proceed is to take the testimony of each of the witnesses and then address questions to the group as a panel.

Our next witness then is Dr. Richard Klein, Department of Botany, University of Vermont. Dr. Klein, we are grateful to you for coming such a distance.

STATEMENT OF DR. RICHARD KLEIN, DEPARTMENT OF BOTANY, UNIVERSITY OF VERMONT

Dr. KLEIN. Thank you, Senator Humphrey, my name is Richard Klein. I am professor of botany at the University of Vermont and codirector of the acid deposition project. Our research is supported primarily by various foundations with some funding from the Vermont Agricultural Experiment Station. For the 3 years prior to September 1983, we also received funding from the American Electric Power Service Corp.

Our research is entirely on the possible effects of acidic, metal-containing depositions on terrestrial ecosystems, especially those of mountainous areas.

Independently of its source, transport or transformation, present depositions are acidic with average weighted pH values of 4.1—at least 10 times more acidic than precipitations that are not anthropogenic and some precipitation events are over 50 times more acidic. Not only is rain and snow acidic, it deposits a significant amount of metals including cadmium, copper, lead, and zinc which have accumulated in the soils of our study areas. Snow produces highly acidic snowmelt that is 10 times as acidic as the bulk snow and solubilizes indigenous aluminum and heavy metals that can then enter the soil water solution and can be taken up by plants. At elevations above 2,000 feet, cloud water, which is five times more acidic than rain and contains higher concentrations of metal, condenses on foliage and hence, the acid and metal load at higher elecations is much greater than at lower elevations. These meteorological and soil chemistry facts are well established.

Our field research started in 1965 and we now possess the best field data base in North America for high elevation forests. Complete floristic and climatic studies in 1965, 1979, and 1983, have been statistically compared. Briefly, our major study area, Camels Hump Mountain, plus other Vermont mountains are disaster areas. In both hardwood ecosystems and in the northern coniferous forest the dominant tree species—sugar maple, beech, mountain and striped maple, red spruce, birch and balsam fir, have shown steady declines in vigor and survival. Fewer than half of the red spruce present in 1965 are alive today and similar, but less dramatic declines have been established for the other tree species. The litter depth—that is the leaves and needles that have fallen from the trees—has doubled since 1965 with corresponding reduction in decomposition and the cycling of scarce nutrients. Mosses that carpet the forest floor and prevent erosion have decreased in coverage by 50 percent. The regeneration of red spruce by germination and establishment of seedlings is almost nil. Once dead, trees have been windthrown and the forest is now an almost impenetratable tangle. These, too, are facts substantiated by appropriate techniques and the sequence of ecosystem failure is also seen in other parts of North America and Europe.

The obvious question and the one which motivates our research is whether there is a cause and effect relationship among the meteorological facts of acidic deposition, alteration in the composition and quality of the nutritive soil solution and the destruction of hardwood and northern coniferous forests in the mountains of New England and elsewhere. Our studies have shown that impacted ecosystems show a particular set of characteristics. They are, in the Northeast, primarily westerly facing slopes of mountains with soils that are shallow to bedrock, naturally acidic, low in nutrients and with high levels of organic matter. These are harsh environments with periods of drought, excess water, wide variations in temperature, and high winds. Trees are continually under environmental stress. It is, we believe, a situation where an additional stress such as acidic deposition becomes too much to bear.

Concomitant with our field studies, we have been developing laboratory simulation experiments in which we isolate a single ecosystem component and evaluate the possibility that this stress—acid, metals, et cetera—can be a contributing factor to the observed decline of the forest. Although time does not permit me to provide you with a résumé of all of our laboratory work, a few highlights will demonstrate our approach and our findings:

(1) Acid loads and metal concentrations that are realistic, repress the activities of soil microorganisms that are responsible for the decomposition of litter and the release of nutrients needed for plants in the forest.

(2) Acidic depositions can leach nutrients from this litter and move these chemicals away from the ecosystem.

(3) Acids and metals depress the growth of moss and can account for the depauperization of the moss coverage on the forest floor.

(4) Acids and metals in realistic concentrations can significantly reduce the ability of red spruce and balsam fir trees to take up and move water and nutrients through the plant.

(5) Acids and metals provided red spruce in hydroponic cultures and kill the plants with the sequence of death mimicking with some precision the sequence we have observed in the field.

(6) Acids and metals in realistic concentrations can reduce the growth of the root systems of seedling red spruce trees, and can cause the death of the seedlings.

(7) Acidic artificial cloud water can leach nutrients, carbohydrates and even proteins from needles of spruce and leaves of birch.

(8) Acids and metals can significantly reduce the growth and vigor of those soil fungi that form mycorrhizal associations with forest tree roots. Many studies have shown that the water and mineral uptake of nonmycorrhizal root systems limits the growth and development of forest trees growing in nutrient-poor soils. We have also found that there are no mycorrhizal associations on the conifeous trees in the upper elevations of our study area.

(9) Metals, solubilized from indigenous and deposited metals by acidic depositions and highly acidic snow melt water, are accumulating in the annual rings of sugar maple and red spruce. Solubilized indigenous aluminum and deposited vanadium in wood have been greatly increased since the 1940–50 period, the time when it was believed that widely dispersed acidic deposition began.

Research is in progress to determine whether there has been a significant decline in the growth rate of hardwood and coniferous trees from Camels Hump Mountain. These studies are not complete, but they should provide a reasonable estimate of the existence or nonexistence of a decline which is, of course, of considerable economic and recreational importance.

We are examining the possibility that the observed and measured alterations in the mountainous ecosystems may be due to causes other than acidic deposition. Disease and insect damage are very unlikely to be directly involved. The evidence, admittedly incomplete, has tended to rule out drought as a major causal factor, although drought is certainly a stress that, combined with other stresses, is a factor in ecosystem destabilization. We have found that in relation to the possible causation of drought, three facts must be brought into the discussion that are involved:

First, our studies, and those that have been done at Dartmouth College, have indicated that although drought has occurred a number of times in the last 150 years, in all cases except the current situation, the trees have survived and they have rebounded and growth vigor has been reestablished. This is not the case today.

Second, trees that were alive in the 1950 and 1960 period are now dying in our study area, and this could not be due to drought.

Third, our evidence has shown that the upper elevations, the coniferous zones, were not dry during the 1950 and 1960 period. The data on there being a drought in Vermont and New Hampshire is applicable to weather stations which are at airports and other low elevation sites.

A fourth point, in relation to drought, is that our simulation studies and our field studies have shown that the sequence of tree death due to drought is very different from the sequence that we are observing in the field.

If the weatherperson on the evening news tells you that there is a 10-percent chance of rain, it is very unlikely that you will carry an umbrella, but if you hear that there is a 90-percent chance—more properly a 90-percent probability—of rain, you're very likely to carry your umbrella. In acid deposition studies as well, we must deal in probabilities, since absolute proof in the legal or even in the scientific sense is unlikely ever to be obtained. Based on our studies, and those of meteorologists, aquatic biologists, soil scientists, and terrestrial plant ecologists and physiologists throughout the world, including, I should note, the excellent work that is being done at Hubbard Brook, there is a very high probability that acidic depositions are the primary and proximate cause of the destabilization and disruption of terrestrial forested ecosystems of mountainous areas in New England and elsewhere. We and others have not been able to provide an alternate explanation that is consistent with all of the available facts.

Our research has suggested that a reduction in deposition acidity from its present 4.1 pH to a pH of 4.6 or 4.8, which requires a reduction in SO_2 and NO_x emissions as proposed by your committee, will go a long way toward relieving the present situation. Even with such a reduction, it is very likely that some damage may now be irreversible.

We are the first to admit that no one has unequivocal proof of the contention of an acid-metal causation for forest damage; additional research will certainly narrow the gaps in our knowledge, but it will never be fully adequate simply because of the complexity of terrestrial ecosystems. We believe, however, that the evidence is sufficiently strong at this time and the probability is sufficiently high to warrant legislation to reduce SO_2 emissions by at least 10 to 12 million tons and there should be an equivalent reduction in NO_x.

I am submitting for the record two manuscripts recently presented at scientific symposia on acid deposition that contain the data to support the statements that I have made today.[1] Thank you for inviting me to participate in your critically important work.

Senator HUMPHREY. Our next witness is Dr. George Tomlinson of the Domtar Research Center, Senneville, Quebec.

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[1] Retained in committee files.

Dr. Tomlinson. Would it be well if the next speaker goes so we don't waste time while I'm getting set up?

Senator Humphrey. Yes; Dr. Kenneth Kimball of the Appalachian Mountain Club, headquartered in Gorham.

Dr. Kimball, welcome. Good morning.

STATEMENT OF DR. KENNETH KIMBALL, APPALACHIAN MOUNTAIN CLUB

Dr. Kimball. Senator Humphrey, the Appalachian Mountain Club appreciates the opportunity to testify on the serious problem of acid rain. The Appalachian Mountain Club is a volunteer, nonprofit organization of some 30,000 members dedicated to wise stewardship of our natural resources. One of the objectives of the club is to explore the mountains of New England and adjacent regions, for scientific purposes. To meet this objective, the Appalachian Mountain Club maintains a staffed research department, which has conducted studies since 1981 on the deposition of acid pollutants on the upper slopes of New England's mountains. The Appalachian Mountain Club's research on the anthropogenic stress has been conducted cooperatively with Yale University, Cornell University and the Cary Arboretum, all who are participants in the Hubbard Brook Experimental Forest.

The Appalachian Mountain Club research during the past 3 years has examined the acidity of cloud and rainwater, which is intercepted by the upper slopes of the White Mountains in New Hampshire. I would like to share with you some of the results that we have received during the last few years. During the summers of 1981 and 1982, weekly bulk rainwater samples from the slopes of Mount Lafayette at an elevation of approximately 4,100 feet and Mount Washington at an elevation of 5,100 feet, had a median pH of 4.20, with the values ranging from 3.6 to 6.5. Cloudwater samples at these locations had a median pH of 3.61, with the values ranging from 3.2 to 4.7. This means, No. 1, that the cloudwater is much more acidic than the already acidic rainwater. Second, it means that the cloudwater is some 98 times more acidic than the acidity of theoretically pristine water, which would be a pH of 5.6. Chemical analysis of both the cloud and rainwater collected at these sites show the acidity to be caused by the strong acids—sulphuric and nitric acids. Though not directly comparable due to differences in analytical techniques, cloudwater measurements of pH on Mount Washington during 1939–40 by Dr. Hutton from MIT—had a median pH of 4.35, with a range in values of 3 to 5.9. This means that the cloudwater that Dr. Hutton had measured in 1939 to 1940 is actually less acidic than the rainwater that we are seeing passing through right now.

Much controversy now exists on whether the mountain forests of New England are experiencing a dieback due to acidic deposition.

The Appalachian Mountain Club recognizes that measuring pollutant levels in precipitation is not synonymous with measuring the effects of acidic pollutants on ecosystems. However, we are particularly concerned with the loading rates of acidic pollutants on the forests and alpine areas at the higher elevations of our mountains. Well over 50 percent of incoming precipitation at higher elevations can be intercepted cloudwater, which is extremely acidic. Cloud cover on the summit of Mount Washington, as you probably know, averages some 75 percent annually from sunrise to sunset. Currently it is unknown what impact the "bathing" of the upper slope forests and alpine vegetation in acidic clouds has. However, we do know from preliminary studies this year that the cloudwater dripping from alpine plants has a greatly reduced acidity. The storms that pass through with an acidity in the clouds of approximately 3.9, by the time we measure the water dripping off the alpine plants, this water has an acidity of approximately 5.5, which means that a strong neutralizing reaction has occurred on the surface of the plants. The type of stress that's being put on the mountain floor by this naturalizing action is unknown; it will become the focus of our research next year.

Unfortunately, few long-term data sets on the impact of acidic pollutants on terrestrial ecosystems exist now. It will take years to develop such data sets. In the interim, the Appalachian Mountain Club opposes the notion that the Northeastern United States should continue to be an experimental region, exposed to high acidic loads of pollutants, to determine how resilient its forests and alpine areas are to this anthropogenic stress. Mankind has already tried such nationwide perturbation experiments, exemplified by the well-known DDT case example. Our forests and alpine areas are still in a condition worth preserving—let us not continue to use these resources in a global experiment to test where their threshold to acid rain actually is. Thank you very much.

Senator HUMPHREY. Thank you. Dr. Tomlinson.

STATEMENT OF DR. GEORGE TOMLINSON, DOMTAR RESEARCH CENTER, SENNERVILLE, QUEBEC

Dr. TOMLINSON. Do you have a copy of my brief? I brought 25 of them, so there should be.

Senator HUMPHREY. Yes, we have.

Dr. TOMLINSON. There is a brief that I'm presenting on the top attached to the paper recently published. I want to explain that.

During recent years I have become very much concerned with the possible linkage between acid deposition and the dieback of forest trees now occurring in central Europe and in certain mountain areas of Quebec and of the Northeast United States, as described by Dr. Klein and the last speaker. Studies indicating such a linkage have been underway for many years in Germany where the situation is now viewed with considerable alarm. As a member of a committee which has met in Europe several times during the last few years I have had an excellent opportunity to review this European problem with several of the principal investigators, to participate in their workshops and field trips and to examine the problem at firsthand. As other speakers will be discussing the parallel North American situation this morning I will concentrate on the situation in central Europe.

Dr. Bernhard Ulrich and his associates and students at the University of Gottingen have carried out a particularly important series of experiments in the Solling district of Germany. They have established that sulfur dioxide present at low concentrations in the atmosphere is dry deposited and subsequently converted to sulfuric acid on the foliage and bark of trees. In addition, sulfate-containing aerosol particles which create atmospheric haze, and acid-containing fog and cloud droplets are also deposited on the canopy. During periodic episodes of rain the accumulated acid is washed from the canopy. Thus, the total amount of sulfate reaching the forest floor is markedly greater than that contained in the rain. They also observed that the soil, immediately adjacent to the fine roots, is substantially more acidic than a sample of the soil taken a short distance away, this resulting from a net transfer of a portion of the acidity received by the foilage to the fine roots and thence to the soil.

The average total deposition of acid on the Solling plateau of Germany during the period 1969 to 1981 was as shown in table 1. You will notice that the throughfall and stemflow under beech is over twice that in the open area—in the open area, where under spruce it's actually over three times as much. In other words, it's a very much more serious situation because of this intercepted deposition of fog droplets, of the haze, and of dry deposition of SO_2 even in small concentrations.

The concentration of gaseous SO_2 at this location is in the range of 5 to 10 micrograms per cubic meter during the summer and 10 to 20 micrograms per cubic meter during the winter months, while on the average, fog is present during 71 days of the year. So it's more compact than Hubbard Brook, but it's of interest to find out what is happening in such locations. These and other data showed that as a result of wet and dry interception deposition, the forest canopy with its large surface area acts as a major sink for air polluants including unreacted SO_2, as well as that incorporated into aerosol particles, fog, cloud droplets, and rain. The amount of sulfate picked up by the trees' canopies is highly dependent on their location in relation to sources of SO_2, the size and species of the trees, and their exposure to prevailing winds, fog, and the quantity and acid content of the rain. Dr. Klein mentioned that the western slopes are much more impacted than the eastern slopes. This is the experience, of course, in Germany and Czechoslovakia. Conifers, with their jagged canopy profile and their year-round foilage, receive greater acidic inputs than the hardwoods as can be seen from table 1.

Ulrich established that the acid entering the low pH soils of the Solling is dissolving aluminum from mineral substances such as clay which are present, while the sulfate inputs are leaching calcium and magnesium, nutrients required by the tree, from the rooting zone. Aluminum is also leached from the soil but due to its absorption affinity for soil particles, which is greater than that of calcium and magnesium, it tends to displace the latter, with the result that the ratio of calcium to aluminum in the soil solution decreases as these acid-induced changes in the soil proceed. It has been established that the fine roots of the trees, necessary for the uptake of nutrients and water, become increasingly stunted and necrotic as this ratio decreases, with resultant stress in the tree. Fine roots will regrow under favorable conditions, but when regrowth does not occur the inadequate root system results in a reduction in growth rate. The trees thus become increasingly vulnerable to secondary stress from weather extremes such as frost or drought, insect attack, and other pollutants such as heavy metals and ozone.

Bauch, at the University of Hamburg, has examined the root systems of forest trees in 11 districts of Germany. In soils with pH of about 7 at 30 centimeters depth the trees were healthy with good root systems, while in acid soils at pH of about 3.6 at the same depth the fine roots of both spruce and fir were seriously retarded, tree growth rate had slowed down or stopped, and the appearance of the tree showed heavy damage. Bauch found that the damaged trees showed no calcium or magnesium in the cells of the cortex of the fine roots whereas at higher pH these nutrient ions were both present. Calcium is an essential element for fine root growth and its absence can therefore be used as a diagnostic test for acid-induced stress. He established experimentally that aluminum ions will displace calcium from the cells of wood, indicating the probable explanation for its absence in the fine root cortex. Now, this is a very important point because the fine roots are like our intestinal tract which allow the water and food to enter the system, and select the ions we need and reject ones we don't need. And he's found that if there is no calcium in the fine roots, they will not reproduce as they normally do. So, I believe that this is a very important thing to have a diagnostic test. Doctor Klein agreed to send samples to McGill University. I believe they have similar—equipment similar to that in Germany to test this out.

In past years, only a portion of the atmospheric sulfate inputs to the soil has carried through the rooting zone in percolating water. The balance of the sulfate has been held in the soil as aluminum hydroxyl sulfate which, as acidification proceeds, breaks down forming sulfate and aluminum ions with the former leaving the rooting zone at a faster rate than its rate of input. In other words, what has happened has been that the sulfate has been building up in the soil over the years, and now it's beginning to let go. This shows from 1969 to 1981, the changes in stores of various ions. This one is sulfur [indicating]. And if we look at the black, which is spruce, the red is beech, you will find that during this period, the soil was actually picking up sulfur, but during this period it's losing it, and now at an increasing rate as this aluminum hydroxyl sulfate breaks down. This is the aluminum, the amounts being lost. The amounts are very great.

This increase in hydrogen ions which is staying more or less constant in the soil. And over here are the losses in calcium and magnesium.

In other words, we are not having a constant rate of what happens. During this period, they are actually picking up sulfate in the soil. Here where you're finally losing it, it's like bursting a dam upstream. So, this becomes a very important factor.

Changes in the storage of nitrogen in the soil can also result in a rapid loss of acid and nutrients from the soil. Acidic soils contain low stores of available calcium and magnesium. I won't bother reading this, but I will show you the slide.

During 1982, there was a hot, dry year in Germany, the soil temperature was 1½ degrees higher. This is the amount of nitric acid that formed in 1981. These are months, starting at May, January, June, July, and August. So, in October, the amount of nitrate in the soil as nitric acid is a little over 3 milligrams per liter. During the hot year, it's built up, and in this period it was around 55, about 10 times as much. At the same time, the pH of the soil which is here around 4 in 1981, dropped down to around 3.2 this year, then it come up again. You see the soil pH will change.

The living fine roots which were coming along here and the dead fine roots in that area were then in 1982, the living ones came down and—I'm sorry. The dead ones—yes, the living ones came down and the dead ones stayed up.

So, this is a very serious problem that can happen due to weather-induced problems on top of the chemical changes going on. In other words, they have large stores of sulfur and nitrogen in the soil. If for any reason those are triggered to start to leach, then it's going to add acidity to the soil which is not normally considered.

I'm going over to page 4. Oh, what's particularly serious, of course, if nitric acid is formed, then the root system is in poor shape because the roots will normally pick up the nitric acid, that's the fertilizer for it, and if they are not there, they don't. So, the nitric acid leaves the soil carrying calcium and magnesium with them. And work that was done at Hubbard Brook shows that when a tree is harvested, the nitric acid went up to about the same level as this. So, this shows the problem of lack of root systems and high nitrate formation.

On the basis of his observations of the continuing changes occurring in the soil, Ulrich developed a hypothesis which suggested that, unless there is a major reduction in sulfur dioxide emissions, forest collapse, such as that which had occurred near major sources of SO_2 in the industrial Ruhr area of Germany and in Sudbury, Ontario, could take place in many areas of Germany. Although this prediction was treated with skepticism by many, a serious change in the forests is, in fact, occurring at the present time.

In 1982, the German Federal Ministry of Food, Agriculture and Forests commissioned a study which established that 560,000 hectares or 7.7 percent of the total forest area was showing die-back, and that the situation is changing at a higher rate. I'll show a couple of slides to show how fast this is. This is in the province of Baden Wurttemberg where the Black Forest is located. And what they are doing is to use the number of leaves that's been translated. This is autumn of 1980 through the autumn of 1982. A sound tree will have only lost zero to 10 percent of their needles; becoming ill or sick, 11 to 20, 21 to 60, 61 to 99, very sick, and 100 percent, dead. So, what has happened in 1980 was they had about 65 percent showing no damage in varying amounts. And you can see that coming through to 1982, you have got the major part in this area where it's lost 21 to 60 percent of their needles, and up here. So that there is indeed a serious problem. This is on fir.

On spruce in the same area, where no damage was seen in the autumn of 1980, it began to show up in the spring of 1981. You will see that now in 1982, all of the area is showing some type of damage. Now, these are in 17 observation areas in 556 trees where they have actually examined each tree at each of these seasons.

This is in 1982. Nineteen hundred and eighty-three data will be presented later this year, and I believe it's somewhat worse.

This shows the areas of Germany, Federal Republic of Germany, where damage is occurring. The red showing heavy forest damage, the blue light damage. And a group at the University of Hamburg examined the soil in all these locations, and the pH in the soil in every case was 3.4, acidic soil such as Dr. Klein has in Camels Hump Mountain.

The Federal Republic of Germany had set up in the early seventies sulfur dioxide monitoring stations to measure this around the clock, day in and day out, under nine of these stations in rural areas throughout Germany. And on this map— of course, those were not necessarily set up where the forest damage had occurred because they thought because the value was low, it was under 60 micrograms per cubic meter, there would be no damage. But now what they have found is that the highest of these stations of 21 is a place called Hoff near the East German-Czechoslovakian line here, and lowest values in South Germany, 7 here and 7 in the South Bavarian Forest, Baden Wurttemberg.

So, that they recognize that the old criteria where they thought they had a feeling—or rather a floor of 60 micrograms per cubic meter no longer holds. It's this combined action of sulfur dioxide by dry deposition and rain and so on that becomes the factor.

In summary, the concept held early in the last decade that high stacks would dilute sulfur dioxide emission to a concentration below a threshold value at which no forest damage can occur has been shown to be invalid. In the same way neither the pH of rain nor the annual quantity of acid deposited in an open area can be used, by itself, as a criterion for the potential damage to the forest. German studies, conducted over a period of years, have shown that forest trees and their soils form a sink for sulfur emissions, regardless of their form, and thus the total quantity of sulfur compounds deposited must be taken into account. In contrast to some earlier opinions, low pH soils, with their already low stores of calcium and magnesium have been found to be the most vulnerable to the effects of acid deposition.

I'd like to show you one more slide—two here. Yes; originally, the damage was only at the higher levels, but now it's moving down. When I was in Bavaria last spring in the Himmelkroner Forest area of Bavaria, they measured actual measurements of trees. In April 1982, 40 percent were showing light damage. This is spruce. A year later, 40 percent showed total damage. It had moved as quickly as that. Wait now. No; I'm sorry. I'm reading my table wrong; 100 percent—40 percent had shown initial damage, here 100 percent. With fir, 70 and 100. With pine, it had been zero in these two, 100 percent in 1983. Douglas-fir, zero in 1982 and 100 percent, and varying degrees of this type of damage.

The other slide I want to show you was taken at Woods Lake in the Adirondacks by a group at Rensselaer Polytechnic. And the red line here is the amount of sulfur—sulfate precipitated in rain, so these are the amounts through the months starting with April running through for 2 years. The brown is the amount of sulfate deposits under beech, which as you see is higher than that. The green is under red spruce. So, that the tremendous increase in the amount of acid that reaches the floor under conifers is, of course, happening also in North America, and again at Woods Lake probably sulfur dioxide is more concentrated than in New Hampshire. But these things move along. We want to make sure—because it's an accumulated effect, not just a 1-day effect that's happening in the soil. It's what's been happening for years and what will happen in the years to come I believe that are important. Thank you.

Senator HUMPHREY. Thank you, Dr. Tomlinson.

I think I will just proceed from my left to right and ask some questions that have been raised by your testimony. May I encourage the other panelists to join in if they have something to offer. In addition to these particular questions, I will work my way across. You are welcome to jump in.

Dr. Tomlinson, first of all, what is Domtar? You are representing some commercial firm of some kind, are you not?

Dr. TOMLINSON. Well, it's a large multiproduct company with very large pulp and paped interests in northern Quebec where the trees are not in good shape, where I have been concerned about this. I retired as vice president 6 years ago, and the president of the company suggested I stay on as a consultant. He asked me what I thought were serious problems and I said this was one. I have been very lucky in that I have been a member of a number of committees that take me to Europe two or three times a year, so that I have been able to follow this, since I had this as a form of interest. Domtar has no other interests than to hope someday this will protect their forests.

Senator HUMPHREY. What is the name of the company, Domtar International?

Dr. TOMLINSON. Domtar, Inc.

Senator HUMPHREY. Incorporated. Where is Sennerville, Quebec?

Dr. TOMLINSON. It's outside of Montreal. It's a large research center.

Senator HUMPHREY. So, you are devoting your—I don't suppose it would be right to call it retirement, but postexecutive days to research on a problem that affects——

Dr. TOMLINSON. Yes. I'm doing other problems as well, but this one I feel is far more serious than the others as associated with operations in our plant and so on.

Senator HUMPHREY. Inasmuch as the pulp and paper industry is significant and important in our State, I think that your participation in this morning's hearing is very useful.

We all know what the esthetic effects are of disease in forests. What about the economic implications, because as you pointed out a moment ago, that's very important to the State of New Hampshire?

Dr. TOMLINSON. Well, the economic ones are very serious indeed if the trees are dying, as Dr. Klein has testified, and there is no question about it. I have seen them there, I have seen them on Wildcat here in New Hampshire and many other mountains. These are trees that are not cut and not being reproduced but ones where the trees are dying. Now, what they found in Germany is that the area is becoming so hostile to plants that they can't establish new forests without heavy liming. Now, to heavy lime the slopes of Wildcat Mountain or any other in New Hampshire or even more so in Quebec becomes an incredibly difficult thing, and it's really not known how effective that would be. So the problem is to stop it as soon as we can and as soon as we can be sure of the thing.

Senator HUMPHREY. Yes.

Dr. TOMLINSON. I believe we need a lot more research, that this is very, very important. We need far more funding. And even after you get your 10 to 12 million tons reduced, it has to continue to know what's going on.

Senator HUMPHREY. Your feeling that we need far more research, as you put it, is that synonymous with feeling that we shouldn't go forward until we have that?

Dr. TOMLINSON. Oh, no, not at all. What I say is that we may find that we need more than 10 or 12 million tons. The longer we wait, the more serious it becomes because of the accumulative effect on the soil.

Senator HUMPHREY. With regard to your work in Germany, your involvement in that study, how sure are you that the source of the problem is not also or at least additionally mobile sources, automobiles?

Dr. TOMLINSON. Well, that is a factor, there is no question about it. I have concentrated on sulfur dioxide. Nitric acid is a fertilizer, and in good forests, that's great. When it gets to stress conditions such as they have there and such as there is at Camels Hump, then it's an additional problem and very serious, too. But the primary problem, I think, has been sulfur dioxide. And in the many forests throughout the East, I'm sure, where the trees are still getting advantage from nitrates, but eventually that will change.

Senator HUMPHREY. Do you think that Dr. Ulrich's work is applicable to our own situation in the Northeast and southeastern Canada?

Dr. TOMLINSON. Yes. He has got a heavier deposition than we have at Hubbard Brook, although on the mountains it's very high. Studies done at Dartmouth on Moosilauke have shown very high deposition rates there. The one thing that in—at Woods Lake in the Adirondacks where I showed, showed exactly the same pattern in Germany, but about half the amount of sulfur dioxide. It's a question of time. It's the amount times the time in relation to the particular soil. Some of our soils are very, very sensitive to this.

Senator HUMPHREY. You mentioned the need for more research. Are there particular areas, in your opinion, that ought to be emphasized in the research?

Dr. TOMLINSON. Well, yes. I think that the Northeast is a prime example, in Canada and in the States. An awful lot of work is going on in areas where there is very little impaction, where the damage has not been seen and people say, "Well, there is no problem, and later, not now."

Senator HUMPHREY. Are there particular kinds of studies?

Dr. TOMLINSON. Well, I think that we need a lot more chemical work, and the type of thing that Dr. Klein is doing is very important. I think if it could be tied into this diagnostic technique used in Germany, and incidentally, this Dr. Bauch has agreed to exchange samples with McGill, we will be getting samples from Vermont. This will be a very useful piece of information.

Just a tree dying of drought will not lose the calcium from the cortex of its bark. It has to be a chemical stress that's causing this.

Senator HUMPHREY. Thank you, Dr. Tomlinson. I know that you are the long-distance champ here today. You must have come down yesterday. It's hard to get from that part of Canada to this part of the United States.

Dr. TOMLINSON. I came to Boston by air and drove up. Incidentally, I spent last weekend in Randolph, N.H. I'm a very frequent visitor to your State, so I love it very much.

Senator HUMPHREY. That's good. We hope you will come back often.

Let us move to Dr. Hornbeck. Some of the data at Hubbard Brook Station, Doctor, conceivably could be used by those who feel that acid rain is not a significant problem. As you pointed out, there have been short-term ups and downs in these various measurements but that there has been a fairly steady decline, I guess, since 1972. Is that cause for confidence that the problem is going away on its own? What is the implication of that? On first glance, it looks encouraging and perhaps might cause some to drop their guard.

Dr. HORNBECK. I can point out how this information has been helpful to us. The information was gathered together by the Environmental Protection Agency, and as part of the Memorandum of Intent between Canada and the United States. And it shows that regionally, at least, in New England there has been a decline since 1972 in SO_2 emissions. And at the same time we have seen a decline in precipitation. The National Academy of Science says this is very encouraging; it means if we reduce emissions nationwide, that we are going to see a reduction in sulfate in precipitation, and that's how that information is used.

Senator HUMPHREY. Yes.

Dr. HORNBECK. Perhaps where I say a national reduction, I should more properly say a regional reduction in emissions.

Dr. TOMLINSON. Could I comment on that?

Senator HUMPHREY. Yes.

Dr. TOMLINSON. Domtar, when I was vice president of research and environment had something like 80 plants throughout Canada and a few in the States, and in practically all of those beginning in the early sixties, we had problems with smoke, with soot, and with sulfur dioxide because regulations came in for the urban environment. The simplest thing to do is to change to gas where we could or oil where we could and use low-sulfur oil, or to take other mediums. But I think that that is the effect that Dr. Hornbeck has referred to. That, of course was a one-shot thing. Once we had done that, there are going to be no more reductions of that type, so that this is really the situation there.

Senator HUMPHREY. Is it fair to say, then, with regard to the United States that this decline in your measurements is a result of the Clean Air Act?

Dr. HORNBECK. Exactly, yes. That's what is expected or that's what is thought to be the major cause in that reduction.

Senator HUMPHREY. Let me play the devil's advocate here. Why isn't it good enough, since we have had a decline, to let things go as they are?

Dr. HORNBECK. Well, as Dr. Tomlinson pointed out, we have taken off the easy part off the top, the things that are done very simply. And from here on, it's going to be much tougher, much more expensive, much more difficult. And some other strange things happen. At the same time that we are cleaning up the air, removing the sulfur emissions, we are also removing calcium and magnesium which tend to buffer precipitation. So, our acidity hasn't changed basically, and also there is an increase in nitrous oxide which we are seeing, which we need to address.

Senator HUMPHREY. So, then you take no comfort in this decline that you have noted since 1972?

Dr. Hornbeck. Basically, the only comfort we take on this is that it shows the decline in emissions will result in a decline in precipitation.

Senator Humphrey. Why is it, again referring to your testimony, why is it that your study shows that storms that originate over the Atlantic are equally acidic as those which originate over land?

Dr. Hornbeck. That's a puzzle to us, but we think that again it's a reflection of the storms that track over southern New England picking up anthropogenic emissions, the same as they do when they come up across the industrial areas.

Senator Humphrey. Storms that originate over the Atlantic, there are rather few in this part of the country, are there not? Are you talking about low pressures that come up the coastline?

Dr. Hornbeck. That's right. They represent perhaps 10 to 14 percent of our storms from that direction.

Senator Humphrey. They generally draw circulation off the land mass, in any case, even though it might go out over the water.

Dr. Hornbeck. In some situations. The ones we're talking about, they were the ones that tended to originate over the ocean or in the Caribbean and move up without the influence of the Southern United States.

Senator Humphrey. I see. You suggest or state that the evidence suggests that in a worst-case situation, acid rain could cause the soil pH in New Hampshire to be more acid by one pH unit within a short a time as 35 to 40 years. Does that mean from now?

Dr. Hornbeck. Basically, if precipitation remains as acidic as it is right now, those are the kind of changes that we might be able to detect in that timeframe.

Senator Humphrey. What would be the effect aesthetically and economically if that were to happen?

Dr. Hornbeck. I think it's generally recognized that a decrease of one pH unit could be quite drastic, especially in distressed ecosystems that Dr. Klein has been talking about.

Senator Humphrey. I believe you mentioned in your testimony that your research at Hubbard Brook played some part in the National Academy of Sciences' studies. Will you tell us what part you played?

Dr. Hornbeck. Well, basically, the Hubbard Brook data were the only data that the Academy had to draw on for long term trends. In particular, one of their major recommendations was that a reduction in sulfur emissions would result in reduction in acid precipitation, or at least an improvement in precipitation quality. And they relied exclusively on Hubbard Brook data to make that decision.

Senator Humphrey. Well, then, your station played a very significant role inasmuch as your data was the only long term data available to the Academy. That's something in which we take a parochial pride in, whether we are entitled to or not. I'm sure it's nice to be able to note that facility in our State.

Dr. Tomlinson. May I add one more thing?

Senator Humphrey. Yes.

Dr. Tomlinson. Hubbard Brook, Dr. Hornbeck and his colleagues, have played a seminal role in the evaluations of the overall ecology of forested areas not only in the United States but throughout the world. Some of the fundamental discoveries in the last 20 years may be traced directly or through to the studies that are going on at Hubbard Brook now.

Senator **Humphrey**. Well, whose foresight was it that brought us to this position? That's a very lucky thing for us. How did this all begin?

Dr. **Hornbeck**. It began with a whole bunch of fortuitous circumstances in 1955, and at that time nobody could envision that this was going to happen. But it's been a fortunate series of events and people involved. Cooperators from universities all over the Northeast and the Forest Service and just a lot of serendipity.

Senator **Humphrey**. What projects are underway or planned at Hubbard Brook? Are you doing much of the same?

Dr. **Hornbeck**. It's a continuing thing. As we learn, we expand our research projects. We are—particularly in the last 1½ to 2 years, we begun investigating the aluminum problem which we feel is probably one of the major concerns in regard to impact on forest systems. There is a large number of scientists now studying exclusively aluminum and how it's controlled by the forest system.

Senator **Humphrey**. You are probably familiar with the U.S. Geological Survey released earlier this year entitled, "Evidence for Acid Precipitation Induced Trends in Stream Chemistry and Hydrologic Benchmark Stations." The study indicates that on the basis of records from the network of 47 benchmark stations, that there has been a small decline in stream sulfate in the Northeast. Is that consistent with what you found? Do you do research in that area?

Dr. **Hornbeck**. Yes; we see that at Hubbard Brook and it coincides with the decline in precipitation chemistry: Again, a favorable point in terms of telling us that emissions—reduction in emissions will reduce sulfur concentrations.

Senator **Humphrey**. All right. Let's move to Vermont, Dr. Klein. Your studies are at Camels Hump and what other places?

Dr. **Klein**. Our basic study area is Camels Hump. We have additionally investigated other mountains in Vermont, including Jay Peak, Bolton Mountain, Mount Abram, and some work in the southern part of the State.

Senator **Humphrey**. Well, I can personally back up your testimony that there are many areas along that ridge that are nothing but a tangle, as one who has done a good deal of backpacking. I have hiked the entire Appalachian Trail up to the Rutland area and the Long Trail to the Canadian border.

Dr. **Klein**. My congratulations.

Senator **Humphrey**. Thank you, I did that in my earlier days. I think it's a beautiful area and it's a challenging hike at some places.

Before we get into your studies I recall seeing, in the paper 1 week or 10 days ago a story that referenced a study, I can't remember now who did it, but I think it was focused on the Northeast, with regard to these alpine regions. And the conclusion of the newspaper piece was that there is no apparent damage by virtue of acid rain to the alpine regions which would presumably be more sensitive and delicate than the areas beneath them. I wondered if you had read that article or had seen the report on which it was based.

Dr. KLEIN. I'm familiar with it. One of the difficulties we have is knowing what they meant by alpine area. If we are talking about areas that are truly alpine, rather than using the Hubbard Brook term which is a very good one of subalpine coniferous, I'm not tremendously surprised that plants that are, let's say, between lick of the clouds and the summit of Mount Washington are not treed areas in this sense. They are herbaceous with setaes, et cetera, which can be quite resistant.

If they mean subalpine in the sense that these are forested areas in the Northeast which include the spruce, fir, possibly hemlock in some areas as well, as I indicated in my testimony, the primary damage is seen in very specific sites, westerly facing slopes, 2,000 feet and above acidic soils with low calcium, high aluminum, I should add high cadmium and high lead and high zinc to this list, et cetera. So, I found a great deal of difficulty in following what they were talking about in the story, while the New York Times and possibly the Wall Street Journal are very excellent scientific publications, they are not a substitute for seeing it in symposium, and I am lost.

Senator HUMPHREY. What study was it referring to? Do you know who did it?

Dr. KLEIN. No; I do not. It's a study that I have not seen at present.

Dr. KIMBALL. Senator, could I comment?

Senator HUMPHREY. Yes; please.

Dr. KIMBALL. That study, I believe, was done by Catledge and Leonard and it's a study on Mount Marcy. I think they put in the transept it was either in the late fifties or sixties. The point I would like to make is that the method they use, the so-called line-intercept method, that sort of technique has a very-low resolution to define the less common species when they start to fade out. So, the technique that was used gives—normally when a system is put under stress, quite frequently the less common species are the first ones to go. This technique does not have the resolution to pick up that sort of thing. So, that even though they found the major species that are dominant there are still there, it does not necessarily mean that some changes have already set in.

On the other hand, it doesn't mean that something has not happened, either.

Senator HUMPHREY. Thank you. Just a few points of clarification. Dr. Klein, you say in your finding No. 1 that acid loads and metal concentrations that are realistic; what does that mean?

Dr. KLEIN. I'm afraid that's jargon, Senator. The studies on acids and metals that we are doing as laboratory simulations are based upon, quote, "realistic," that is, concentrations and levels that we are finding in the field. That is, it would be unrealistic if, for example, we were to supply our systems with the acid levels at pH 2.0 when we know that it is 4.1, 4.5. The same is true for the metal interactions. Sorry.

Senator HUMPHREY. OK. Point No. 3, what is depauperization?

Dr. KLEIN. That's a good word. That one I'll stick with. Essentially, what we did is a study in 1965 with a quantitative and qualitative restudy in 1979 and 1983. One of the things that we found was that the area of the forest floor that was covered by mosses decreased in the 16-year period by 50 percent. The forest floor has become poorer, depauperized.

Senator HUMPHREY. We all know what that means on April 15. If I ever knew what it meant in the biological connection, I would have forgotten it.

Page 4 now of your testimony, second from the bottom paragraph, "We are examining the possibility that the observed alterations in the mountainous ecosystems may be due to other causes." Will you expand upon that for us, please?

Dr. KLEIN. There are several possible things that one can think of and evaluate in terms of ecosystem collapse. One, of course, is the devastation that can be caused by insects, which has been seen in some areas, et cetera. There is no evidence in these areas that are showing this deterioration that insect damage could possibly be at the level that we are observing. The second one, of course, is disease. This too has been studied by competent plant pathologists in our group as well as in other groups. And the only disease participation that we have been able to find is that after the trees are dead, the fungi that are in there will break down the dead trees into wood. So, we have tended thus to eliminate that as a possibility.

A third possibility and the one that has received a great deal of attention is the one of weather patterns. The concept of drought is one that always has to be considered and so should excess moisture, the flooding syndrome, and often these areas are not subject to flooding. The drought situation is a very difficult one to evaluate because as I pointed out we know that although the Burlington Airport or the Manchester Airport is reporting that there has been no rain for *x* number of weeks, we go up in the mountains and the cloud water is still condensing, the forest floor is wet, and so drought does not appear to be involved.

We have done and are still continuing to do large numbers of studies on tree coring, very carefully done and computerized work. And we can pick up blips of drought. We can pick them up from 150 years and we can get correlations as the Dartmouth group has done for a long time. The recovery and the difference in the pattern of death is such that we tend to eliminate drought as a proximate or primary cause, although it is a forest stress that must come into it as well.

Senator HUMPHREY. Yes. Is it possible that these conditions that have caused the forest dieback and disease are local to these ranges that seem to induce precipitation?

Dr. KLEIN. This is the question that's very difficult to answer at this time. Most of our work of course has been concerned with mountainous areas with relatively or absolutely undisturbed natural forests. The situation because of this is very different from the German experience where the Black Forest is what we would call a managed plantation with the trees lined up in good dramatic fashion. We have not only trees not lined up, but we also have a greater species diversity, so the situation is more difficult.

However, we are beginning now, in the last year since our work has begun to appear in print, the lag between starting research and putting this together, to be getting small reports, some of them anecdotal, that lower level areas are beginning to show the same thing. One of the things that we have found at 1,800 feet is that in 1965 there were ash there. There are no longer any ash, they are gone. These are good sized trees and there were also small ones. We have been picking up information from 1,000 feet, 1,500 feet that ashes are beginning to go. We have anecdotal information about sugar maple, not only in Vermont but also in New Hampshre, New York, and Quebec as well. Is it the same thing? We don't know, except that our data base suggests that indeed it may very well be.

The other thing that I would like to indicate is that in our 1965–79 block of survey, we breathed something of a sigh of relief because the balsam fir did not at all seem to be affected. And we said, well, gee, there will be conifers on the upper elevations as well. We did it in 1983; that's a 4-year spread. The balsam fir are down significant—statistically significantly between 1979 and 1983.

Other species that seem to be unaffected in 1979 are statistically significantly affected now. Whether we are on really an accelerating track in terms of damage, I don't know. I'm not sure that I really want to speculate on it.

Dr. Tomlinson. Could I make a comment there? In Germany they have far fewer species that we have, incidentally, in Germany, but they have brought in things like Douglas-fir and red oak and so on. And all areas—all species in various areas are affected. That is one thing that is quite certain.

The other thing is that in their mountains, instead of being, say, like Wildcat where you have mostly fir on the top, then spruce first, then hardwood with the odd spruce and firs mixed in with them, they will perhaps be fir and spruce all the way down, they have been able to observe the damage particularly in the Chrovanocha Park in Czechoslovakia, where they first saw it on the top of the mountain, then lower down. I have seen pictures taken at an elevation which might be, say, equivalent to the first chairlift on Wildcat, where that looked perfect 5 years ago and now it's devastation. So it is a syndrome that moves down as the soil becomes less and less capable of handling the trees.

Senator Humphrey. Thank you. Dr. Klein, just one or two more questions.

It's your feeling, then, I take it, that you feel your findings principally along the ridge in western Vermont are applicable to the forests of New England in general; is that correct?

Dr. Klein. The evidence that we have from our group in correlating that with, for example, the very detailed studies at Whiteface Mountain, other mountains in New England including parts of Mooselauke and some of the Quebec experience seems quite precise. But we have not yet completed a study being done under contract with EPA to survey the health of red spruce throughout its growing range in the United States. We were not allowed into Canada as part of our survey. We have found what we are calling at the moment for lack of a better name, hotspots in which there is significant damage to red spruce. Some of these are as far south as West Virginia in the upper mountains there.

Senator Humphrey. Yes.

Dr. Klein. The syndrome of death or ecosystem destabilization and the geographical and meteorological evidence from these areas is the same: Westerly facing slopes, thin soils, acid soils, low calcium, et cetera.

We believe that this does apply generally. We have also been in contact with people working in the Sierras, where up until about 1978, 1979, there was virtually no visual damage. They're beginning to find that the pattern is the same of soils, et cetera. So I think that it has a considerable amplitude in terms of significance.

Senator HUMPHREY. All right. Finally, your statement that it is likely that some damage may be irreversible; would you expand on that, please?

Dr. KLEIN. On Camels Hump and other Vermont mountains and other places throughout the Northeast including New Hampshire and Maine, the northern coniferous forests consisted basically of balsam fir and red spruce with balsam fir tending to be in larger quantity than red spruce. Our failure to observe the regeneration of red spruce not only on Camels Hump and elsewhere, suggests that it is likely that given—what's the word, worst possible—worst-case scenario, that red spruce will fall out of the ecosystem. This deprives the ecosystem of an important component, reduces the diversity of ecosystems, and may in time, particularly if the damage continues to drop at elevations, as George Tomlinson has pointed out, may have a great deal of economic impact. I'm not a forester, but it's my understanding that red spruce is used in the pulp and paper industry as one of the species mix components to make craft paper bags and other utilitarian paper. If it decreases, if it disappears, there will have to be a technological alteration in the pulp and paper industry, which has significance.

Senator HUMPHREY. All right. I discovered one more point I wanted to touch on, then we will go on. One more, if I may.

Dr. KLEIN. Yes.

Senator HUMPHREY. Apparently your study has been criticized by scientists with the Electric Power Research Institute. Are you familiar with that critique, and can you address that?

Dr. KLEIN. Yes, I am familiar with that critique. Sorry to be long-winded. As I indicated at the beginning of our testimony, we were supported for 3 years by the American Electric Power Service Co., a large integrated electric power generating holding company, with holdings throughout the Ohio River Valley on down through West Virginia and even Virginia. Most of their power is generated from coal in these States. We were asked, and properly so, to provide them with progress reports during the course of our association with them. We did so and found out only this summer that our internal documents were then distributed rather widely to the industry and that the industry had hired people to evaluate and critique them.

We received those critiques this summer. I have gone over them. My major comment at this point right now is that the critiques were based upon a report which was not a scientific document, and hence we are at something of a loss to go any further until, as is occurring now, our scientific papers come out and are evaluated with all of the data, all of the controls which were not in our preliminary reports.

Senator HUMPHREY. So the critique focused on preliminary reports and not the final report?

Dr. KLEIN. Yes. Not the final report nor on our scientific papers which have been published in periodic journals.

Senator HUMPHREY. All right. Thank you. Sorry to keep you waiting so long, Dr. Kimball.

Why are the rain samples which the Appalachian Mountain Club has collected in the years 1981 and 1982 not directly comparable to those taken in 1939 and 1940? By the way, who took those earlier, was that the AMC?

Dr. KIMBALL. No; the 1939 and 1940 samples were taken by Dr. Hutton from MIT. We have been basically working on trying to improve the technique of collecting cloud samples right now. One of the major problems we have in collecting cloud samples on the summit of Mount Washington, we are dealing with relatively strong winds. There is a tendency for the rainwater to get entrained with the air masses that are moving through the cloud collector. So that what we actually pick up in our cloud collectors is cloud water plus rainwater. This actually means that the median pH values that we are giving you for cloud water right now are actually somewhat higher than they should be because the rainwater is actually less concentrated in acid than the cloud water, and as these samples pass through now, what we do have is a mixture of these two. So our cloud water samples are diluted.

In answer to your question, though, is that when Dr. Hutton did his study, he went out and just grabbed portions of storm events that were passing through. We know during a storm event now that the pH can change by as much as one pH unit. Consequently, we—but we do not have any records on what part of the storms he collected, so you have to be a little careful when you do your comparisons here.

Senator HUMPHREY. Do you have any idea of what part of weather systems are more acidic than others, the leading edge of an air mass? Do you have any thoughts on that?

Dr. KIMBALL. Well, we find with cloud water sampling is that an event can come in as a cloud event and turn to rain and the acidity tends to get reduced during the rain portion of a storm, probably due to a washout effect. Then if it turns back into a cloud event, the acidity tends to increase.

Senator HUMPHREY. You have noted that, as have others who have been there, I guess, that 75 percent of the time the top of Mount Washington is surrounded by clouds. That's true along the Vermont ridge, too. I don't think it's that high, but anyone who hikes up there knows it rains as often as not, at least it's very wet. The bathing of mountains and ridges and clouds, evidently, is more than the rainfall; is that correct?

Dr. KIMBALL. Yes, that is very true. And I would say that the higher you go, the more serious the problem is as far as having it bathed. In fact, I would say the summits of the White Mountains of New Hampshire probably get a much higher acidic exposure than many of the mountains that Dr. Klein looks at just simply because they are in the clouds more often.

Dr. TOMLINSON. That shows up in the throughfall type of information I had presented earlier.

Senator HUMPHREY. What conclusions are you able to draw so far on the data you have gathered?

Dr. KIMBALL. Well, as I mentioned before, we did do some preliminary studies this summer to see what was happening to the alpine vegetation that is exposed to this cloud water. There is no question that strong neutralizing reactions are occurring on the surface of these plants. I would be premature to say how strong the stress of this is because we simply have not had time to look at it.

Senator HUMPHREY. What additional studies would you suggest at this time?

Dr. KIMBALL. I think we need a lot more data bases like what we have at Hubbard Brook, the long-term cumulative monitoring techniques are the same so that we do not get confused by the problems of trying to compare one technique to another and so forth.

Senator HUMPHREY. In your view, is there sufficient study of the more typical terrain areas? I know the resources are limited, but so far we have been concentrating on mountain peaks and ranges, whereas a large part of New Hampshire is not that pronounced; it might be fairly high, but it wouldn't be described as a peak or a ridge. Are you doing research in those areas?

Dr. KIMBALL. There is ongoing research. For example, I know in Massachusetts, they are taking a look at the acidity in a lot of lower elevations, ponds, and so forth. I know in Cape Cod, the buffering capacity is down. There is some evidence that some ponds out there are now being acidified. But you have to understand, as you get to lower elevations, the amount of soil above the bedrock, et cetera, becomes thicker so the buffering capacity is greater, so you expect the reactions actually to happen first at the higher elevations as opposed to lower elevations.

Senator HUMPHREY. Well, all right. I want to thank our first panel very much: Dr. Tomlinson, Dr. Hornbeck, Dr. Klein, Dr. Kimball. Thanks very much. We appreciate your help in this matter.

[Dr. Tomlinson supplied the following information:]

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November 15, 1983

Senator Gordon Humphrey
Environment and Public Works Committee
United States Senate
Washington, D. C. 20510

Dear Senator Humphrey:

I was pleased to have the opportunity to present a brief at your hearing in Concord on October 14th. You may recall that in my discussion of the decline of forest trees in Germany I referred to the accelerating loss from the soil of the tree nutrients calcium and magnesium and to the accelerating rate at which toxic aluminum is entering the soil solution. Professor Ulrich, of the University of Gottingen, who has been carrying out such measurements over the last fifteen years had predicted in 1979 that the accumulative year-after-year effect of acid deposition on the poorly buffered soils in Germany could trigger forest collapse.

On October 18th, 1983, the German Federal Minister of Food, Agriculture and Forests issued a statement which stated that the area of forest damage in that country increased from 8% to 34% from 1982-1983. A copy of the translation of this document is enclosed.1/

I believe that in view of the high ratio of acidic deposition in the North East U.S., and the apparent vulnerability of the poorly buffered soils found in many areas, these developments in Germany should be closely followed.

Sincerely,

G. H. Tomlinson
Senior Scientific Advisor

1/ The document referred to has been retained in committee files.

Sortie 40, route Trans-Canadienne ouest
Sortie 40, Trans-Canada Highway West

Senator HUMPHREY. Our next witness is His Excellency, the Governor of New Hampshire. Good morning, Governor. We are delighted to have you with us.

STATEMENT OF HON. JOHN SUNUNU, GOVERNOR, STATE OF NEW HAMPSHIRE

Governor SUNUNU. It's a pleasure to be here. It's always a pleasure to share a couple of tables with you. I hope things are going well.

Senator HUMPHREY. Yes; up until now, anyway. You are free to proceed as you wish. Will you be bringing us up to date on the efforts of the Governors Task Force? Is that your effort here today?

Governor SUNUNU. I will. I must emphasize, though, although I'll be bringing you up to date, I don't want my testimony to be construed as representing the task force; and that is merely a matter of protocol that the task force is officially charged to report to the executive committee of the National Governors' Association in Chicago on October 21, and I would hate to preempt any actions or alterations of policy that may take place in the executive committee. So, I am here as Governor of the State of New Hampshire, and incidentally, I will give you a progress report as to where we stand.

Senator HUMPHREY. Fine.

Governor SUNUNU. But it is certainly a policy that is in transition and flux and in the process of being created, although I don't anticipate major changes, I think we have to speak to the reality of that possibility.

First of all, I do appreciate the chance to talk about the issue, Senator. I think that a lot of us, yourself very much included in the forefront, have become very active, very concerned, and very much willing to address and constructively the issue associated with acid deposition that takes place really across the eastern half of this country. And one of the problems associated with it is the reality that any time we have an impact of this magnitude, that there is an appropriate relationship between the Federal Government and the States and even local governments involved in the process to make a responsible—to responsibly address the situation. And it is clear to me that at some point appropriate legislation at the Federal level must be enacted in order to constructively deal with the issue.

I would first of all like to speak in a chronological sense to bring you up to date as to what has happened at the Governors Task Force. And I want to emphasize again what I said at the outset that this is sort of a summary report. It by no means indicates a final position of that group.

First of all, the Governors recognize the issue as a crucial one. At the last National Governors' Association meeting, we formed a task force and asked me to chair it, to provide a framework for policy for the National Governors' Association. I think I ought to explain what is done with policy—formal policy statements by the NGA. The NGA is a gathering together of the Governors of this country. And in those issues where they can, come to a conclusion that is representative on major policy issues of at least two-thirds of the Governors of this country, establish policy frameworks that are utilized by the Governors in concert to press for legislative actions to take place or press for policy decisions to take place out of the Federal framework. That is what we are aiming to have here; a policy statement that the NGA can take and utilize, to be very blunt about it, to lobby for constructive legislation on the issue.

It is not intended to be a substitute for the specific framework that might be used in legislation. It is to be a policy statement on which lobbying efforts can be focused to either support or oppose specific pieces of legislation. And I think it has to be understood in that context so that there are neither too great nor too small a level of expectations involved in Congress.

We proceeded in a very tight timeframe to act to develop an understanding of the issue and then an establishment of the relationships we feel that ought to be included in legislation that balance what we think are a variety of legitimate constituencies involved in a question of variety of legitimate perspectives that must be addressed in any legislation that is both effective and fair. And I think fairness is an important issue that has to be part of any legislation that comes out.

I will not dwell on all the details of the specific policy that was developed by the task force, except to say that I think it is notable to emphasize that that task force which consisted of 12 Governors had on it five Governors from midwestern States that are States, that by all credible technical analyses, are the principal emitters of the SO_2 that is a major contributor to the acid deposition that is taking place.

Those five Governors certainly had very strong political, geographical, economic, and from the point of view of appreciation of the environmental impact, a variety of perspectives that they have to concern themselves with that were perhaps slightly different than what we in the Northeast would assume to be the level of priorities and the States of the West would be the level of priorities. I think that as a Governor I share with those Governors a recognition of the fact that they do have a local more parochial interest that has to be considered in the part of developing process—policy and processes. And I think to the credit of the task force, that task force that did have five midwestern Governors that might be perceived to be of the States that might be perceived to be the ones that would more directly be affected by legislation that came out of Washington did come to a very strong support for a policy statement that said there would have to be significant levels of reductions.

I don't think there is any question in examining the context of the discussions that significant levels were associated in the context of our discussion with a phased approach, a two-phased approach. The early phase was of the order of 3 to 5 million tons, and the second phase was 3 to 5 million tons of reduction, which I think is very much consistent with the overall approach that has been suggested by a number of people in terms of the size and magnitude of an effort that has to be addressed. And I am pleased that we were able to get the support of some of those midwestern Governors in that recognition of the problem and a commitment to support an effort by the National Governors' Association to move toward that kind of legislation. And I think that although there is some concern—has been some concern raised that significant is not specific enough in quantity, that the important point is that the task force had to address it from the breadth of constituency that was represented there, and even with that breadth of constituency, that there was clear support for that kind of policy statement.

There are other pieces to the policy statement that are very important. The Governors feel very, very strongly that whatever program is enacted must include a component of funding for research and development as well as data collection and assessment of impact and assessment of the benefits of any program that is enacted, as well as research and development for alternative technologies that can make significant contributions to the level of reductions we are talking about.

They are very strong in their concern that this be part—not only part of the program, but a significant part of the program.

In addition to that, in recognition that there are effects already taking place that have to be addressed, the Governors felt very strongly that there has to be a significant component in legislation that addresses mitigation efforts, including lake liming; that we address the impacts that have already occurred in the process.

The other part of the program that was discussed addressed the need to deal with the variety of growth patterns that are occurring in this country. And although there are many States that can survive the economic distress that would be imposed by a variety of policy perspectives such as capping emission levels at a given period of time, there are some States whose both economic and population growth will be disproportionately large over the next decade or two and that has to be considered in that process. And therefore, an across-the-board cap is one of the perspectives that the Governors felt should not be part of any policy.

I would be remiss if I didn't point out that in the process of getting to this policy we discussed a number of specific aspects that might be considered within legislation. And although at a variety of times they have received staff support, they were never formally endorsed by Governors. But I think I should at least from a very personal and as Governor of the State of New Hampshire perspective talk a little bit about the interrelationships of some of the specifics that might be in legislation, because I really do think that sound legislation will have to balance the specific needs of the various segments of the country.

I will try and reduce, if I can, to simply, some may say overly simplistic, but I think it is the key to understanding to get it down to as simple as possible a set of concerns that are, I think, representative in each and every case of slightly different constituencies.

First of all, in terms of impacts, the impacts are clearly not felt uniformly across geography. The impacts on environment are very crucial in the Adirondack region, certainly in the mountainous regions of the vicinity of West Virginia and so on. In terms of environmental assessment, those are the crucial areas.

We suggest that if a policy for determining which States must participate in any given program, that there be some consideration given to some of the parameters that are contained in reports such as the National Academy of Science, that sets some measurable, certainly not definitive, but measurable and quantitized boundaries for assuming participation in emissions and the relationships between those emissions and deposition. For example, the National Academy of Science talks about 1 thousand kilometer impact region. We used that at one point to assess a variety of programs and a variety of combinations of States for participation in programs. It is perhaps not inappropriate that legislation include in its something more than just an arbitrary sampling of States, but be based on some technically founded basis as that for determining the States that would participate in the process.

In addition to that, we recognize that the principal contributor in the process is the burning of coal, and yet we also understand in that generalized statement, that very general statement, that there is a distinction amongst classes of coal, and that that itself represents a variety of constituencies. And in its most basic and simple terms, there are those regions that mine high-sulfur coal and those regions that mine low-sulfur coal. And I think that any legislation that fails to understand the reality of the impact that this might have on job distributions throughout the country does not really fairly address the economic impact that Federal legislation might have, and at least should address any severe impact on employment in such a way that they can be faced appropriately without too much of a disruption of the employment patterns within the either high-sulfur mining or low-sulfur coal mining areas.

To put it in a geographic sense, the Midwest, West Virginia are clearly areas that have a relationship toward the high-sulfur mining areas. There is current heavy employment of miners in those areas, and they are States that would be severely—significantly concerned about a policy that eliminated the potential use of high-sulfur coal from the energy mix of this country.

On the other hand, the Western States have significant deposits of low sulfur coal, and there are some deposits in the Appalachia area as well, and they too would be concerned about a solution that merely allowed the—or almost forced the postburning cleanup of high-sulfur coal as the only alternative. In other words, a strategy that forced scrubbers or excluded scrubbers; each one extremes of an overall strategy and I think can be compromised and balanced and be made fair and should be considered in the specifics of the legislation.

In addition to that, there are other perspectives that ought to be addressed in terms of fairness that also have a geographic base to that. The New England States have done significantly well in addressing the problems of sulfur emissions and have made significant investments generally at a cost of the consumers of this region in providing a very strong response to both the spirit and letter of the Clean Air Act and have done a great deal in terms of the investment in cleaning up the emissions that take place in our region.

Certainly, the same thing applies to the Western States. The Far West feels as we do, that they too have made the investment necessary in order to clean up their emissions. There are other parts of this country that feel that way. The Southern States feel that way. And, therefore, any legislation that comes into place that is going to provide financial incentives for the remaining areas, in particular, the Midwest, to address the problems of emissions must for fairness sake somehow build into it a recognition that other regions of the country, the citizens and consumers in those areas have already made significant contributions generally through the electric rate system for cleaning up their part of the problem to begin with. There has to be some way of taking into account the constructive character of actions already—that have already taken place. And that, too, is a level of constituency concern that I think has to be addressed in the context of the legislation.

The other point that I think is a significant one from a national perspective is that it is erroneous to assume that the level of technology that we have in place today is the level of technology that will be available in 3 years or 5 years or 7 years or 10 years, particularly if a national commitment to dealing with this problem is made. It is very impressive to see what can be done when technology commits itself to improve on the solutions that are available when the fiscal incentives of commitment of large sums of money in addressing problems are made in terms of a policy commitment that this Nation might make.

So, I really do think that there is a very important national value to providing for a phasing of a program that allows us to implement today as much as possible the most cost-effective technologies we have at hand; that provides a financial incentive for the development of further technology, and allows for a timing process to bring on line at appropriate time in an effective, timely manner the new technologies as they are developed. This too, I think is—has to be a very important part of any legislation that is put together.

The third—the next point I'd like to address is the size of the program in its various phases. I really do think that it is not appropriate to put a program into place whose phasing is such that there will be no perceptible positive benefit in the phasing process. There was nothing that would discourage the continuation of a program more than a program that is undersized in its initial aspect. And for that reason, I think that the program has to be not only a representative program or an experimental program, but a definitive program that has, to use the word the Governors used, a very significant first phase at least to it.

In addition to that, the fairness of the funding process has to be built into it. And this addresses one of the issues I touched upon already, that some areas of the country have already made significant investments. There is an appropriate perspective that argues very strongly that the funding process should merely be based on a concept of having those that are emitting, those that are polluting now be the payers of the process. That, generally, comes down to a concept that essentially says there should be a surcharge or a tax or fee, whichever phrase you prefer, on emissions of SO_2 that are currently taking place, both as a way of funding the program and as an incentive to encourage people to reduce those emissions.

There is a second philosophy that suggests that we have recognized this as a national problem, that those that emit are not necessarily those on which there has been significant environmental impact or economic impact, and therefore recognizing it as a national problem, there should be a national component to the funding process. That, generally, comes down to an argument that it should be taken out of the general Federal Treasury expenditures, or an argument that suggests they tax a fee or a surcharge on the generation of electricity generally limited to fossil fuel fired electric generation.

I feel that there is a validity in all the perspectives that are brought to that, and I feel that some kind of a compromise is appropriate. One of these more popular compromises that were discussed within the Governors Task Force was a compromise that said once we decide what annual funding levels we are going to contribute to, that those funds be raised 50 percent from some kind of a general charge based on the formula addressing the emitter concept, a tax or surcharge on emissions, based on emissions, and then 50 percent in terms of a tax or surcharge on fossil-fired fuel—fuel generated electricity.

That may be one of the more difficult questions to deal with politically. I think that almost any packaging that addresses the concept in a fair way would be an appropriate one. With all due respect, though, I must urge that we do take into special consideration or at least part of the consideration the fact that New England and some of the Western States, the Far Western States are States in which the most expensive electric rates exist. The San Diego area, the southern California area, and the New England region are two regions of the highest level of current electric rates, partially because we have already as a region and as consumers made our investments, and in establishing that formula for distributing the charges, I as a Governor of a New England State urge that special consideration be given to what we have already invested in the past and will have to invest in the future.

Those are the basic pieces, Senator, that I think ought to be considered. For the most part, the specifics are really my own point of view and my own perspective. They come from a bias that I think has been developed over a number of years of experience as an engineer and certainly as one that has been involved in the energy area for a long time. Whatever legislation has to—that comes about has to address the urgency of the problem as well as to address what I think is still a valid concern for sound energy policy in this country.

Coal is still our principal energy resource. We must come out with legislation that maximizes the capacity of this Nation to use its coal resources rather than minimize it. And I think here is a classic opportunity for leadership from Washington, certainly in response to the leadership given by the Governors of this country, but an opportunity to do something right and to do something well.

I have one last point, Senator, that I would like to make because it is an issue that to me, unfortunately, represents some of the more emotional response that is made to this issue in an unwillingness sometimes to examine specific details of statistics. And that is the public perception that has been created that our good neighbors to the north have taken a leadership role in this issue.

With all due respect, I tell you exactly what I told the Canadian premiers when you had a meeting with them. I think there has been more lipservice and less action from the north than there has been from this country. And I give you some statistics to ponder.

The level of sulfur SO_2 emissions in this country is about 24 or 25 million tons a year. The level of those emissions in Canada is about 5 million tons per year. We emit five times as much as the Canadians. I pointed out to the Canadian premiers that they have 10 times the population—that the United States has 10 times the population and

15 times the industrial output. Therefore, on a per capita basis, they are emitting twice as much as we do, and on a per unit of industrial output basis, they are emitting three times as much as we do. If they ever achieve the 50-percent reduction that they give strong lipservice to, and I have my doubts that they will even do that, and their commitments is to try and get there some time in the mid-1990's, by that time they will then only be where we as a nation are today. The fact of the matter is that there has to be a more significant real commitment on their part, particularly from the major smelting operations that they have, which there is some technical evidence to suggest that on a per pound reduction can be done even more economically than some of the utility reductions that we would have to bear.

I hope that you might convey the reality of these statistics to your colleagues down there because I am constantly distressed by people saying we have to do at least as well as the Canadians are going to do. We have already done significantly more than I think the Canadians may ever do, and we ought to at least give ourselves credit for, I think, a very successful national effort in response to the Clean Air Act.

Thank you very much.

Senator HUMPHREY. Thank you, Governor, and I want to commend you on your statement, the clarification of the purpose of the Governors Task Force paper. It is very helpful. I do believe there were some misconceptions about what it stood for. As I understand it, I see it to be more than helpful. As a member of the national legislative body, I am only too painfully aware of the need to reconcile the regional differences if success is to be had in passing a bill. I know that as a political practical matter we have to do that. I, certainly, agree with your observations. To the extent that, and I suppose the extent has been significant, to borrow a word that you Governors like to use, I suppose that your participation as chairman of the task force has been significant in bringing around the Governors of the Midwestern States who in turn, I think, will be very instrumental in bringing around Midwestern Senators and bringing around the Senate and the House to pass a bill.

I think I am more and more convinced that the task force has helped enormously, and I congratulate you for your part. I might add to that, without being partisan, that I think everyone in New Hampshire is proud that our Governor happens to be the chairman of that task force. He wasn't chosen by lot, as far as I know, but on the basis of technical competency.

Governoir SUNUNU. Thank you, Senator. I do want to say that through the process, a very constructive spirit of cooperation coming from Governors of States that are principal emitters. And if I may point out, that I think one of the inspirations for it was the concern that legislation would not equitably address some of their specific needs, and that cooperation, I think, can be developed even further by giving some consideration in proposed legislation to some of the real economic disruption that could occur if we are not constructive in our approach; and that the penalty, and that even may be too strong a word, for including in legislation appropriate consideration of their needs are not significant at all, and yet the benefits that would accrue economically to this Nation are very significant.

Senator HUMPHREY. Fine, Governor. We thank you for your participation.

We welcome our next panel: Ms. Jackie Tuxell, chairperson, New Hampshire Citizens' Task Force on Acid Rain; Betsy Ham, New Hampshire Sierra Club; Dr. Larry Frederick, Public Service Company of New Hampshire; Mrs. Marcy Lyman, policy coordinator. Society for the Protection of New Hampshire Forests; Dr. William Wallace, director of Public Health Services, State of New Hampshire. Thank you for coming and sorry to have kept you waiting so long, but it could be worse; you could be on the third panel, I guess.

Let's take the testimony in the order listed on the agenda, beginning with Ms. Tuxill. Good morning.

STATEMENT OF JACQUELYN TUXILL, CHAIRPERSON, NEW HAMPSHIRE CITIZENS' TASK FORCE ON ACID RAIN

Ms. TUXILL. Thank you very much, Senator. My name is Jacquelyn Tuxill, and I am representing the New Hampshire Citizens' Task Force on Acid Rain. I appreciate the opportunity to present testimony on the need for a national acid rain control program and the importance of such a program to New Hampshire.

The Citizens' Task Force represents a number of individuals and a variety of conservation, public health, educational, and public interest groups from all over the State.

Organized in 1980, the task force seeks to heighten public awareness of the acid rain problem and encourage citizen participation in a legislation solution.

Let me say from the outset that it is our position that a national program to reduce sulfur dioxide emissions by 50 percent is needed immediately to begin to reduce acid rain. Such a program may be critical to the future health and well-being of New Hampshire's citizens, natural resources, and economy. I am also using the term "acid rain" with the understanding that this popular term also includes all manner of acid deposition, wet and dry.

In order to determine the importance to New Hampshire of an acid rain control program, we need to examine what is happening in the State. Since many of these impacts will be explored in greater depth today by other speakers, I will just mention them briefly

The precipitation falling in New Hampshire is approximately 40 times more acid than normal. According to the New Hampshire Water Supply and Pollution Control Commission, the median pH of the precipitation in the 52 storm events sampled in 1982 was pH 4.

The ability of some of our ponds and streams to sustain life is threatened. In May 1983, Water Supply and Pollution Control Commission surveyed 36 high mountain ponds, the most vulnerable ponds, testing for pH and alkalinity or buffering capacity. Of the 36 ponds tested, only one had an alkalinity measurement above 10 milligrams, a point which indicates buffering capacity is practically gone.

Many scientists studying forest ecosystems are concerned with the threat to future forest productivity from acid rain. There is concern as well over the effects of aluminum that is mobilized in the soil and toxic metals that are also a part of atmospheric deposition.

The potential for acidified water supplies, which can leach lead and cooper from old plumbing systems, is a public health concern. The presence of other toxic metals can also threaten the quality of public water supplies.

Acid rain can speed up the deterioration of monuments and certain building materials and corrode paint and metals.

Acid rain as a phenomenon is spreading. In the mid-1950's, areas in the Eastern United States receiving acid rain were concentrated in the Northeast. Today the area being subjected to acid rain has spread to include all of the Eastern States as well as areas farther west. While New Hampshire and other Northeastern States may be more vulnerable to certain effects of acid rain because of granitic bedrock and thin soils, other impacts such as foliar damage to trees and plants, decreased visibility, structural impacts, the potential threat to public health posed by breathing fine sulfate particles—can be felt wherever acid deposition occurs.

Acid rain is also an international problem, with Canada's environment and economy being affected, as well as foreign relations between the two countries. All of the foregoing facts coupled with the phenomenon of long-range transport, demand a national solution to the problem.

Calls for acid rain control have come from a variety of prestigious study panels over the past several years, including the National Commision on Air Quality in 1981 which recommended a significant reduction by 1990 in SO_2 emissions in the Eastern United States; the National Academy of Sciences which concluded in 1981 that a 50-percent reduction in deposited hydrogen ions was necessary to signficantly reduce the rate of deterioration of sensitive freshwater ecosystems.

In a January 1983 report, the Canadian Summary of the United States-Canada Working Group proposed that deposition of sulfate in precipitation be reduced to less than 20 kilograms per hectare per year in order to protect aquatic ecosystems. In New Hampshire this translates into approximately a 50-percent reduction in the sulfur loading.

In June 1983 a White House-appointed panel of scientists recommended immediate and significant reductions in sulfur emissions from coal-burning powerplants and factories. This White House Office of Science and Technology Policy panel did not feel that acid rain control should wait for a greater degree of scientific certainty. And they said in their report that it is quite in the nature—I quote,

> It is quite in the nature of the acid deposition problem, that actions have to be taken despite incomplete knowledge . . . If we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of "irreversibility".

Finally, another National Academy of Sciences report released in June 1983 goes one step further to confirm the heretofore "missing link" between SO_2 reduction and reduction in acid rain. The Academy concluded that on a regional basis, reduction in SO_2 emissions would lead to a directly proportional regionwide reduction in acid deposition.

Quite a few acid rain bills have been introduced into Congress this session. The Citizens' Task Force has not taken a specific stand on any of the bills, but has continued to state that several key elements are absolutely critical to an effective control program. These essential elements are:

First, the acid rain control program must have an overall goal of 50-percent reduction in SO_2 emissions.

Based on the 1981 National Academy of Sciences report, this is the reduction necessary to begin to reduce the deterioration of sensitive aquatic ecosystems. It should be noted that this was considered a "significant" first step; we consider a 50-percent reduction in SO_2 to be the minimum acceptable reduction.

Second, the geographic control area should be the 31 Eastern States at a minimum.

There are rumors circulating that the Reagan administration may propose at the most a 4-State 2- to 4-million-ton SO_2 control program. This is totally unacceptable. The 1983 National Academy of Sciences report talks of the atmospheric mixing of pollutants over a wide region, and, from trajectory analyses, concludes that midwestern SO_2 emissions contribute to acid rain in the Northeast. An acid rain control program must address sources throughout the Eastern United States, and this control region must be spelled out in the legislation, not left up to administrative discretion.

Third, interim reductions must be required.

An interim reduction schedule is necessary to begin to ease the acid overload in the Northeast. The timeframe usually proposed for reduction is 10 to 25 years. There must be some assurance that progress toward the reduction goal is being made prior to the final deadline to avoid a delay. Any phasing of reduction requirements should clearly be mandatory steps toward the overall goal of a 50-percent reduction, and not subject to administrative discretion.

Fourth, cost-sharing must be accompanied by a full 50-percent reduction in SO_2.

The final and perhaps most difficult element to be considered in designing a national acid rain control program is who pays. Traditionally with environmental control programs, the polluter pays for the pollution he or she releases into our "environmental commons." While in actuality some of these costs may be passed on to the consumer, the basic philosophy remains that the polluter bears the control costs.

We are not necessarily opposed to cost-sharing per se being proposed, but we feel it should be made clear that this is a change from past policy. Cost-sharing must be accompanied by assurance that the reduction will be effective if we want to get our money's worth.

One final point with respect to costs is the cost of not doing anything. Costs in the Northeast have been estimated to be at least $2½ billion per year with one estimate placed at $5 billion. Consideration of damage nationwide would raise that figure. These costs should be brought into the equation whenever costs of controls are discussed. If through a cost-sharing scheme we are asked to help pay for a reduction program with less than a 50-percent reduction in SO_2 such as the four-State proposal, then not only will we have to pay the direct costs of instituting controls but we will also have to bear the continuing environmental costs of a less than complete reduction program.

In closing, I want to point out the extent of the public support in New Hampshire for an acid rain control program. Last spring at 199 town meetings across the State, the citizens of New Hampshire had the opportunity to debate a resolution calling for a 50-percent reduction in SO_2 emissions and the adoption of a treaty with Canada committing both nations to that goal. The resolution passed in 197 towns, and was tabled in 2, with no defeats. The city councils of Keene and Nashua passed similar resolutions last fall, while city councils in Claremont, Somersworth, Lebanon, and Franklin have all passed resolutions in the past several months. This overwhelming show of public opinion is unprecedended in New Hampshire's history.

Thank you again for this opportunity to comment on this most important problem.

Senator HUMPHREY. Thank you, Jackie. Our next witness is Betsy Ham, New Hampshire Sierra Club. Good morning.

STATEMENT OF BETSY HAM, NEW HAMPSHIRE SIERRA CLUB

Ms. HAM. Thank you, Senator, for this opportunity to testify, and I might say that I think it's very important that we do have such hearings in New Hampshire, a State that is really most concerned about acid rain. I think Jackie Tuxill gave a very good summary of how all environmental groups feel about acid rain and what should be done. I'd like to stress a few things.

First of all, I think it's no wonder that New Hampshire residents are concerned about acid rain. Our rains are 40 times more acidic than normal, and considering our tourist industry is based, to a large extent, on freshwater activities, this certainly could threaten our economy. Acid rain is a New Hampshire problem. It's also a national problem.

In California, acid fogs were reported to have a pH of 3.0. In the Rocky Mountains, lakes are very susceptible to acid rain. The Adirondack region in New York State has over 200 bodies of water that now contain no life because of acid rain. And a little closer to home, in Bennington, Vt., the townspeople of that area have to treat their water with a buffer so that the toxic metal lead does not leach into the water system because of acid rain.

This problem requires immediate attention. Our lakes certainly won't wait for us to decide what should be done about acid rain; they will continue to die. In fact, the National Academy of Sciences has said that by 1990 the number of lakes threatened by acid rain will double. So, we must do something about acid rain now.

And since acid rain is a national problem, we have to approach it at the national level with some sort of legislation passed through Congress. And again I must stress the urgency of this problem.

I believe that there are five points that should be included in any national reduction program.

The first point, as Jackie Tuxill outlined, is a 50-percent minimum reduction in sulfur emissions. The National Academy of Sciences has set a pH of 4.6 as the level at which no damages have been observed to date. By reducing at least by 50 percent in sensitive areas in the country, we hope to get up to that pH level and to stop acid rain.

My second point is that there should be a cap on nitrogen and sulfur oxide emissions at the 1980 level. And I might point out that this cap on emissions does not necessarily mean a cap on growth. There are many ways to cap emissions without restricting growth. For example, old plants that are less inefficient and pollute more can be phased out with new plants that are more efficient and pollute less.

Because of the need for immediate action, we believe that a large percentage of these reductions should occur in the first 5 years of the program, and that all reductions should be completed by 10 years. And by reductions, I'm referring to the sulfur oxide reductions by 50 percent.

Because this is a national program, my third point is that nitrogen oxide emissions have to be considered and that these should be reduced as well for the Western States which are affected most by nitrogen oxides.

There should be no tradeoff between reductions in nitrogen and sulfur oxide emissions. The National Academy of Sciences recommends that sulfur oxide emissions should be reduced by 50 percent. A reduction of any less than this, even if it is coupled with an increase in nitrogen oxide emissions reductions, will not stop the damages being done by acid rain.

And, in conclusion, I would point out that no bill so far introduced in Congress has effectively addressed all these five points. In order to achieve the reductions necessary to stop acid rain, current legislation must either be amended or new legislation must be introduced in order to stop acid rain.

In order to get strong legislation passed on the acid rain issue, we urge that the New England delegation unite behind one bill that includes all these five points in order to get fast and strong legislation through Congress.

Thank you very much, Senator, for this opportunity.

Senator **Humphrey**. Thank you. I'll talk to my colleagues immediately.

Our next witness is Dr. Larry Frederick, Public Service Co. of New Hampshire. Doctor.

STATEMENT OF DR. LAWRENCE FREDERICK, PUBLIC SERVICE CO. OF NEW HAMPSHIRE

Dr. **Frederick**. Mr. Chairman, I'm Lawrence Frederick on behalf of Public Service Co. of New Hampshire; we thank you for the opportunity to speak to you on this important subject.

The issue of acid precipitation, or acid rain as it is called, is clearly a serious concern among New Hampshire residents. It is also a concern at Public Service of New Hampshire. Because we live here too, we also stand to be affected not only by acid precipitation's impact on the New Hampshire environment, but also by efforts to address that problem.

Many challenging questions have been raised about acid precipitation. Is the acidity in precipitation increasing? If so, how much damage is it doing to the environment? How much of such an increase is caused by human activity, and how much originates as part of the natural process of our changing environment? What precursor compounds cause the alleged increase and where do they come from? How is acidity transported? Does human activity in one region of the country create acid-forming compounds that are then transported by air movement and precipitation into other regions? And finally, can we, humans, control the amount of acidity in our environment to any measurable degree?

More specifically, the issue centers on the amount of acidic precipitation allegedly caused by Midwestern coal-burning powerplants and the effects this acidic precipitation has on the regions of New York, New England, and the eastern provinces of Canada. These and many more similar questions are the subjects of intense studies commissioned by the Interagency Task Force on Acid Precipitation, the Electric Power Research Institute, and others.

Unanswered questions notwithstanding, New Hampshire residents have expressed a strong desire for implementation of remedial measures. New Hampshire's government leaders at the State and Federal level have taken the lead in pushing for public policy decisions that might mitigate acid precipitation. We support those efforts. We do, however, want to offer some words of caution.

It is true that opinion surveys have shown, and also town resolutions, have shown that public opinion favors preservation of the environment, despite the costs. But that does not mean the public is not concerned about those costs. If reasonable decisions are to be made, it is important that the public is aware of the costs as well as the benefits of various approaches to addressing acid precipitation. We, therefore, hope that New Hampshire's government leaders will keep the State's residents apprised of the potential economic impact of acid precipitation proposals under consideration.

Because of uncertainty regarding the economic relationship between dollars spent to address the problem versus expected benefits, steps taken should be carefully measured to best match benefits with costs. Also, it is important that any national proposal to address acid precipitation takes into account regional factors. For instance, consumers here in the Northeast have been paying a higher price for electricity because utilities in this region burn lower sulfur fuels than utilities in other parts of the country, particularly those in the Midwest. Northeastern consumers should not bear a disproportionate share of the economic burden associated with any new measures designed to mitigate acid precipitation.

So, we believe there is a need for a national program to address acid precipitation, and we recognize the importance of such a program to the heatlh and environment of New Hampshire. However, because of the many unanswered questions, we urge that measures are well-reasoned, that consumers are fully aware of the costs of those measures, and that residents in the Northeast are not forced to pay a disproportionate share of those costs.

In the meantime, Public Service urges and will continue to support research on acid precipitation to more clearly define the problem, and to find solutions that produce maximum benefit at minimum cost.

Thank you very much.

Senator HUMPHREY. Thank you, Dr. Frederick.

The fourth witness is Mrs. Marcy Lyman, policy coordinator for the Society for the Protection of New Hampshire Forests.

STATEMENT OF MARCY LYMAN, POLICY COORDINATOR, SOCIETY FOR THE PROTECTION OF NEW HAMPSHIRE FORESTS

Mrs. Lyman. Thank you, Senator. And I am here on behalf of Paul Bofinger who extends his regrets that he was not able to attend.

I'm not going to read all of the statements which you have before you. I would simply like to reflect on a couple of things that have been brought up in previous testimony including some of the information which we have in the Society's testimony.

I'd like to comment on Dr. Klein's comment that we have to deal with probabilities. And I, certainly, support that and agree with it. I think along those lines, we know our precipitation is acidic. We know our aquatic ecosystems are being damaged. Our forests, which cover over 80 percent of the State, providing raw materials to our forest industry, an important land base for recreation and tourism and a valuable investment for many private landowners who are not immune from the effects of acid precipitation.

While we have little documented evidence on the damage in New Hampshire, our review of research from Canada, Vermont, and Europe gives us reason to be gravely concerned over the health of our forests—and for good reason:

We have recently heard reports that several white pine stands in the southern portion of the State show significant progressive decline in growth over the last 20 years. And while additional research is needed to determine whether these occurrences indicate a trend and to identify the cause of such a decline, we cannot ignore the fact that this may well represent the fate of our forests—and if so, the implications are enormous, both to the economic and job losses and disruption in the forest products industry, recreation, tourism, the private investment of the landowners, and human health.

We urge that a national program to reduce acid depositions focus specifically on providing meaningful reductions in sulfur dioxide emissions. And in meaningful, I mean 50 percent minimum.

I want to respond to Public Service's comments. We are willing to pay. The citizens of New Hampshire, I think if polled would indicate that they recognize that they pay already, but because the losses that will result from acid rain are such that we are willing to contribute even more. However, if that's the case, we want a meaningful program.

And finally, in addition to a national program, I think, judging from the information that we received from our first panel that there is emerging an enormous data base on the effects on the forests. And I would urge a prompt, coordinated, and of course well-funded effort to get the information out on the effects of the forests in the Northern New England area. And I would recommend addressing, among other things, the extent of growth decline in white pine and to see whether similar trends are developing for other species such as ash, white oak, sugar maple, that many of the other speakers have mentioned.

Finally, if I may speak as a representative from the Citizens' Task Force, I, with all due respect to Governor Sununu, I must comment on his remarks regarding Canada's role in this issue. The citizens of the State of New Hampshire, and I would like to extend these remarks to our guest from Canada, feel very strongly that this is a problem shared by both countries; that we should not be adversaries in it. While we recognize that Canada does need to do some additional reductions, they have, in our opinion, taken the first step, whereas the United States has not. And we share the concern with the citizens of Canada and hope that we can work with them to solve the problem.

That concludes my remarks, and I thank you very much for the opportunity to comment and also for your aggressive work in trying to solve the problem.

Senator HUMPHREY. Thank you. Dr. William Wallace, Director of Public Health Services of the State of New Hampshire.

Doctor, before you begin, I'm glad that we have someone from Public Health here because I wanted to know if it's true if we reduce acid precipitation, my hair will grow back. Is that true? I hope so. Is fallout caused by acid rain?

Dr. WALLACE. Do I have to comment on that?

Senator HUMPHREY. In your circumstances, no.

STATEMENT OF DR. WILLIAM WALLACE, DIRECTOR, PUBLIC HEALTH SERVICE, STATE OF NEW HAMPSHIRE

Dr. WALLACE. Thank you, Senator, for this opportunity to speak here. As you indicated, I am director of the State's division of Public Health Services. I'm not here today really as director of the division of Public Health. It was known that I was going to come and listen to the proceedings today and I was asked late yesterday to be a pinch-hitter for Dr. Stephan and to read the statement from the New Hampshire Lung Association. I am, however, a member of the board of directors of the Lung Association, and that's why I was asked to make the statement. I'm not the expert Dr. Stephan is in this area, but here to present the statement and to read it into the record.

This morning we have had a number of comments on the environmental threats posed by this phenomenon called acid rain. I would like to address the health effects posed by sulfur oxides, one of the precursor pollutants of acid deposition. As you are no doubt aware this insidious pollution can fall to Earth as dry particles as well as in other forms of precipitation, such as rain, snow, sleet, hail, fog, et cetera.

It is this dry fallout that poses the greatest potential for harm to humans because the sulfate particles can be inhaled deeply into the lungs. All of the regulated air pollutants can affect the body through the respiratory system and although the National Ambient Air Quality Standards are set to protect the health of all people with an adequate margin of safety, there are subgroups of the population who are more sensitive to the effects of air pollution. These include the young, the elderly, the unborn, and the chronically ill: That is those with chronic heart and lung diseases. And this segment of the population has been estimated to include tens of millions of the U.S. public.

Current control programs generally require only limited consideration of the effects of long-range transport. Available information suggests reductions in emissions of sulfur oxides would result in reductions in the levels of these fine particulates. Therefore, the American Lung Association as well as the New Hampshire chapter support programs to achieve significant reductions in emissions of sulfur oxides from major stationary sources.

Acid rain control legislation, by mandating reductions in emissions of sulfur oxides, has two benefits: Reduction of an environmental threat, and reduction of the concomitant public health risks.

Recent research findings showing effects on pulmonary function from short-term exposure to sulfur dioxide at 0.25 part per million, and to sulfuric acid at 100 micrograms per cubic meter. Given these findings, according to current scientific information, the margin of safety associated with air quality standards may well be inadequate.

It would seem that the recommendations of the National Academy of Sciences and the panel selected by the White House Office of Science and Technology Policy released in June of this year should be heeded. The main points stated: Action should be taken now to reduce the emissions of sulfur dioxide; establishment of an acid rain control program should not await further study; reducing sulfur dioxide emissions will reduce acid rain. A significant reduction in sulfur dioxide emissions can reduce the acidity of rain by as much as 50 percent. Sulfur dioxide emissions from the Midwest do contribute to acid rain in the Northeast.

It's the feeling of the New Hampshire Lung Association that Congress must immediately adopt and provide for the enforcement of legislation to control the emissions leading to acid deposition. And we look to this committee to take a leadership role in initiating this effort.

The New Hampshire Lung Association thanks you for this opportunity to participate in today's hearing. And along with my statement, I have also left a variety of articles on the general health effects of air pollution.

If I might, just for a moment, however, since I did get the chance to be up here and didn't have a prepared statement on this, I do want to make one other comment on suggestions of the other possible health effects of acid rain.

I am a member of the Acid Rain Coordinating Committee by virtue of my position, and some months ago I discussed with my epidemiologist, who is an assignee from the Center for Disease Control in Atlanta, the potential effects and neurological effects of acid rain. One of the issues that has been raised is the potential problem of acid rain causing increased leaching of heavy metals, including aluminum, from the soil into the ground water and surface water. Excess drinking water aluminum theoretically could contribute to the development of human neurological diseases, including amniotropic lateral sclerosis, Parkinson's Disease, and Alzheimer's Disease.

There is some evidence that the increased incidence of severe neurological disease at least in some native South Pacific populations may be related to diets containing a chronic surplus of aluminum and deficiencies of calcium and magnesium. Laboratory analysis has revealed high levels of aluminum in the drinking water of these people. And autopsy examinations have demonstrated accumulation of aluminum in the central nervous systems of patients who have died with severe neurological disorders. At present there are no good data to support or refute a theory that the apparent relation between aluminum ingested and illness in South Pacific natives may also hold for New Englanders chronically ingesting drinking water polluted by acid rain.

And I would simply suggest from that information and the relative paucity of the information in the literature on these effects, that further study is urgently needed in this specific area, and any legislation that is drafted on a national level should include some provision for much more study into the area of the epidemiological effects of acid rain as a health risk.

Thank you.

Senator HUMPHREY. Thank you, Dr. Wallace.

Now for the questions, and again I will simply go from my left to right for reasons of simplicity.

Mrs. Lyman, you mentioned indication of a progressive decline in the growth of white pine stands. I understand that's based on a study which is so far preliminary. But can you expand a little on that, and tell us something more about that?

Mrs. LYMAN. I don't feel entirely comfortable doing that. It was presented by Dr. Olson to the Forest Society at our annual meeting. He cautions that these trends—well, they're terribly preliminary. He is going around the State now trying to gather more information on different kinds of stands of white pine to try and confirm what he is suspecting. I think what it does is point to the need for developing that kind of information based in New Hampshire.

Senator HUMPHREY. You went to some pains to state that our neighbor, Canada, has been more responsible in dealing with its problem than the United States has been. I'm not trying to pick a fight between nations here, or between Governors and Senators, but can you tell us what these steps are that Canada has taken that we haven't taken?

Mrs. LYMAN. I don't want to open up a Pandora's box, either, but I felt it was incumbent to at least respond that, at least from the perspective of the people of New Hampshire, that we have felt that Canada has contributed in large part to the research information which has been developed. They, certainly, have been working on recognizing the problem long before we did officially, and sought to find information that would be helpful in resolving it.

I understand that Canada has agreed to, and has actually committed itself to reducing their emissions by 25 percent with the understanding that an additional 25 percent would be reduced when an agreement between the United States and Canada could be reached.

I would reflect, also, upon the figures that I have tucked in the back of my mind, that 90 percent of their acid rain originates from sources in the United States. I believe that's correct. And only 10 percent of ours, I believe, originates from Canada. So, there is already an imbalance. I think that we have a responsibility to respond to the challenge with which the Canadian Government has put to us.

Senator HUMPHREY. I would certainly agree with your observation that the level of national leadership, the Canadians have been ahead of us. I hope that is changing. I believe it is, based on my private conversations with Mr. Ruckelshaus.

Mrs. LYMAN. We look forward to that change.

Senator HUMPHREY. Doctor Wallace, this aspect of dry fallout and inhalation is one that I haven't seen or dealt with before in public. No doubt it has been in medical circles. It's an interesting and certainly understandable phenomenon.

Have there been any studies? What are the health effects of inhaling dry—what do you call it, particles?

Dr. **Wallace**. Once again, not having put this together in terms of comments, some of the backup information in terms of articles that have been submitted do indicate that. But in terms of the sulfur oxide, and this is not the acid that we are talking specifically about, but the other forms of pollution, do have an effect on the chronic pulmonary function. In this case, those—the greatest at risk population are those with chronic heart disease and chronic pulmonary disease, whether they be youngsters or old folks. So, there is that element of breathing the air in general not specifically related to acid rain, but obviously if something is done to reduce the sulfur dioxides, in general this is going to have a positive effect on reducing some of these health risks as well as one reducing the acid rain. So, I can't be specific in terms of personal knoweldge of those, not being in pulmonary health care myself.

Senator **Humphrey**. OK. Are there times when this dry fallout is more prevalent than others? Again, I realize you are pinch-hitting here.

Dr. **Wallace**. Once again, I can't say, but I would assume when there is drier weather is when you are seeing much more of that.

Dr. **Tomlinson**. It's a period of haze that we often get that, I think, is responsible for this inhaling of the particles. That same period is one that's heavy in dry deposition on the leaves.

Senator **Humphrey**. I'm having respiratory problems just thinking about it. Going to the leaching process, have there been any studies that you are aware of in the Northeast of lead pipes, or what is the status of the public water supply in general? Do you have any information on that relative to the effects of acid ground water?

Dr. **Wallace**. I don't believe there have been any specific studies at all. I know there have been none in New Hampshire in terms of relating to any health conditions or specific diagnoses.

One of the things that I was discussing with my epidemiologist before he went for another assignment was the kinds of things we might do in New Hampshire in terms of retrospective studies, looking at people with diagnoses of Parkinson's Disease or Alzheimer's Disease and looking at individuals that are living with those conditions in rest homes and nursing homes, that kind of situation, and tracking back retrospectively into their water supplies and doing that kind of retrospective studies as opposed to a prospective study where you take a controlled community and affected versus nonaffected people. Looking at the kinds of diagnoses in communities that do have a higher level of aluminum, for instance. But I do not believe there are any formal studies, at least linking the health effects. There are statistics through the Water Supply and Pollution Control Commission as to the presence of metals in water supplies.

Senator **Humphrey**. Well, the possible connection between acid ground water and its effect on drinking supplies and Alzheimer's Disease has been introduced recently. Can you tell us something about that; on what that hypothesis rests, what the effect is, and so on?

Dr. **Wallace**. My understanding is, again not having been personally involved, is based on the study of the South Pacific group where they really did find a statistically very significant correlation between the level of aluminum in the drinking water. It was an association with the calcium deficit as well. And a high percentage of neurologically affected individuals in the postmortem examinations, you know, finding there to be a significant amount of change.

There is an individual in the State of Vermont, I have not personally dealt with him, but again my epidemiologist, Doctor Haran, was in communication with him. Doctor Purl, who has been doing some things in terms of a study of autopsies over a period of time in trying to put something together in terms of what's going on in this area.

I would think any studies that are done ought to be on a regional basis and perhaps not just a statewide basis because of the smallness of numbers. We need enough numbers to become statistically significant.

Senator HUMPHREY. Well, that evidence then comes from the South Pacific. Are there any similarities in the soil or rocks of the continental United States that might make it likely that the same thing is occurring here?

Dr. WALLACE. That I don't know. Obviously, the aluminum is getting into the soil through the acid rain. And I'm not personally familiar with that particular study.

Senator HUMPHREY. That's an interesting aspect.

Dr. TOMLINSON. Doctor Purl is an associate of Doctor Klein's at the University of Vermont. He recently sent me three of his papers. So that through Doctor Klein you could get the information.

Dr. WALLACE. We should get those papers. I think we need to look more into this area of health effects.

Senator HUMPHREY. Yes; it's an area that hasn't had much attention so far and one that could be significant, I think, just because it all seems so logical.

Doctor Frederick, how much is it going to cost ratepayers to clean up the emissions? I know that's tough to answer, but it's a good question.

Dr. FREDERICK. It will cost. There are many proposals around, both within the administration and in Congress, and it all depends on which proposal you are talking about.

We haven't evaluated every one of the proposals. They are as numerous as leaves in the wind. But when the first proposal came out, the Mitchell bill, S. 1706, we did do a cursory analysis on that. We didn't have any idea of what we were up against as far as cost exposure is concerned.

And when that came out, the Edison Electric Institute did have a study done on that bill which indicated State by State the amount of emission reduction that should take place.

We used that number, applied it against our system, not any of the industries in the State, but assumed that we would take that full burden and that we would take it in 1-year's time, because although we were given something like a 10-year spread to achieve the reduction, the way that would be distributed over the 10 years is not up to the utility but is up to State government. So we have to assume as a worst case that it would take 1 year.

The data base that went into that study done by EEI was on 1978 and 1979 emission factors, not 1980. So right there we had a lot of uncertainty. It didn't seem to warrant a very sophisticated analysis, because we were interested mainly in orders and magnitude type thing. And as you are well aware, the orders and magnitude type of thing that we came to was in the tens of millions of dollars for our system. It required reductions in the sulfur contents of fuel at all of our plants, including our Merrimack Station in Bow. This roughly $50 million per year reduction amounted at that time to about a $5 per month per customer increase.

Senator **Humphrey**. That's worst case?

Dr. **Frederick**. That was the worst for that particular bill. Our analysis achieved what we wanted. We didn't have any idea of what kind of exposure we were up against. And that served the purpose. That number that we arrived at, whenever it's quoted. I have to assume that it's plus or minus 15 percent anyway. But even in that case, it's still a lot of money.

Senator **Humphrey**. Taking again the worst-case scenario based on that bill, $5; how much is that as a percentage of the typical household bill in the State per month?

Dr. **Frederick**. Typical household bill would be—per year it's about $600. Per month, $120, so you would be adding on to whatever that percent happens to be. But things have changed since then.

Senator **Humphrey**. Excuse me. Will you pull your mike in closer?

Dr. **Frederick**. I said things have changed since that time. That estimate probably needs to be updated.

Senator **Humphrey**. For my own personal use, I'm trying to get some ballpark figures here. Somehow I missed what you said. What percentage increase would you say?

Dr. **Frederick**. Well, if the typical bill is $120 a month, then you are adding $5 on that; whatever that percentage happens to be.

Senator **Humphrey**. Less than 5 percent, in any case?

Dr. **Frederick**. Less than 5 percent. There have been other estimates that have come out since, but not generally. I would mention the one in Business Week we saw that the Electric Consumers Resources Council projected the effect within the States that were incorporated under the EPA—one on the EPA optional scenarios, that an increase of about 13 percent in residential rates would be required to encompass that, and 20 percent in industrial rates. That would have translated into something applicable to us, something in the order of $80.

Senator **Humphrey**. You say that there are a number of intense studies commissioned by the Interagency Task Force on Acid Precipitation. What is the Interagency; is that a governmental group? What is that?

Dr. **Frederick**. Yes; that is. They recently came up with their annual report.

Senator **Humphrey**. That's at the Federal level. OK. What then is the Electric Power Research Institute doing in their studies?

Dr. **Frederick**. They have been doing quite a few things already. They are engaged in a 5-year research program now which is funded for about $450 million. A lot of these cooperative programs have involved EPA, Department of Energy and whatnot. This recent cap deck experiment that took place for release of inner gas near one of the powerplants in Ohio was a joint venture, it was partially funded and supported by them, and it was quite involved.

Senator HUMPHREY. When will we see a report of studies?

Dr. FREDERICK. I'd be very interested in seeing that report myself. That was the first shot. Apparently that cap deck experiment goes on for several generations. I would be very interested in seeing the results.

Senator HUMPHREY. Are these principal studies going to be completed soon? Can we expect those results soon or are they very long term?

Dr. FREDERICK. Some of them are long term. None of this is conducive to short-term looks. As has been said, a lot of this depends on statistical buildup of data to get some kind of handle on our ability year by year.

Senator HUMPHREY. I can understand that. Speaking of government leaders, in pushing for public policy decisions that might mitigate acid rain, you say: "We support those efforts." Does that mean you support passage of legislation at this point?

Dr. FREDERICK. We are supportive of legislation that makes sense.

Senator HUMPHREY. Oh, forget it. If you think Congress is going to pass anything sensible, forget it.

Dr. FREDERICK. Our charge is to provide power as reliably, as efficiently, and as cost effective as possible. And we would like to be able to tell our customers that for the money spent there will be a measurable benefit.

Senator HUMPHREY. Of course. So, what is reasonable? What is significant? It's hard to pin those things down. What do you consider reasonable? Are any of the bills pending reasonable in the eyes of Public Service?

Dr. FREDERICK. I can't say.

We evaluate them, we look at them. But as I say, we haven't run any detailed economic analyses on those things to see how they affect our company.

Senator HUMPHREY. OK. You say in your statement, "* * * because of the many unanswered questions, we urge that measures are well-reasoned * * *" What unanswered questions are there from your point of view?

Dr. FREDERICK. Unanswered questions? Will, in fact, a reduction in emissions result in a measurable decrease—or rather increase in pH; the most profound question of all.

Senator HUMPHREY. Don't you feel that question was answered by the NAS study?

Dr. FREDERICK. The NAS study did come out with some conclusions, but it dealt mainly in regionwide generalities. They said that over the entire region a reduction in SO_2 emissions will yield a decrease in acidity.

Senator HUMPHREY. A linear decrease, yes.

Dr. FREDERICK. But, over an entire region. But whether it applies specifically to a small region, what economically is the advantage of that.

Senator HUMPHREY. Well, what are you referring to as a small region?

Dr. **Humphrey.** The confines of New Hampshire.

Senator **Humphrey.** Well, we, in Congress, have a lot more to do than to deal with the problems of New Hampshire, we have the whole region, the whole northeastern region, indeed the whole United States. We have to address it on a national basis, don't you agree?

Dr. **Frederick.** You have to address that on a national basis.

Senator **Humphrey.** Yes; do you agree with that?

Dr. **Frederick.** Yes.

Senator **Humphrey.** Then, why is it relevant to wonder about whether it will work on a State-by-State basis?

Dr. **Frederick.** Because we own and operate in the State of New Hampshire.

Senator **Humphrey.** OK. Public Service continues to support research. What kinds of research do you wish to see?

Dr. **Frederick.** Well, the kind of research we support is the kind that we would be charged to do. We are a member of EPRI and therefore contribute to the EPRI research budget.

Senator **Humphrey.** I see. Speaking of New Hampshire, what would Public Service do if it had to reduce sulfur dioxide emissions from its plants?

Dr. **Frederick.** It depends on the magnitude. At the very minimum, we would probably achieve that through the purchase of fuels with lower sulfur content.

Senator **Humphrey.** Lower sulfur coal?

Dr. **Frederick.** Yes; and oil.

Senator **Humphrey.** And oil. Is that what you would do down at Bow, for instance?

Dr. **Frederick.** If we had to, yes.

Senator **Humphrey.** What sort of coal are you burning there?

Dr. **Frederick.** As I think I indicated before, the kind of coal that's burning there is coal that has a low-melting point because of the peculiar characteristics of that combustion unit. It's called a cyclone-fired plant. This operation depends on having coal with a low-melting point.

Senator **Humphrey.** How does that equate in terms of sulfur content?

Dr. **Frederick.** There isn't a correspondence. There isn't necessarily a one-for-one correspondence. What the problem is is that typical coal seams, with coal of that characteristic, are usually not low-sulfur coal.

Senator **Humphrey.** So it's high-sulfur coal?

Dr. **Frederick.** Not as high as the highest.

Senator **Humphrey.** Where does it come from?

Dr. **Frederick.** West Virginia area. We do know of the existence of coal seams with those particular low temperature characteristics and low sulfur coal characteristics, but they are not developed enough for us to go in and immediately tap them off. We would have to go through extensive alterations and transportation problems at those mines.

Senator **Humphrey.** Where are they?

Dr. **Frederick.** They are also down in that area.

Senator **Humphrey.** Your switching to coal—is that Schiller over at the Piscataqua River?

Dr. **Frederick.** Yes.

Senator HUMPHREY. You switched to coal. What sort of coal are you going to be burning there?

Dr. FREDERICK. That is not the same kind of coal. That would be a low sulfur coal, 1.4 percent sulfur content. But it need not have the low temperature content characteristics of the coal being burned at the Merrimack Station.

Senator HUMPHREY. OK. Ms. Ham, point 2 of the recommendations: "The bill should not include a cap on emissions at the 1980 level." You feel that can be done without restricting economic growth. Will you expand on that, please?

Ms. HAM. Sure. I hope I said it should include a cap on sulfur dioxide emissions.

Senator HUMPHREY. Beg your pardon. If you did, I meant to say that.

Ms. HAM. As I said in my testimony, I think many older plants that are less efficient could be phased out with newer plants that are more efficient; let's say, for example, that one old plant might be phased out in favor of two new plants that are more efficient. I think as long as you do this in a controlled way, as long as you keep track of it nationwide or on a State-by-State basis, you can do it without decreasing growth considerably.

Senator HUMPHREY. Dr. Frederick, if there were a cap, how would that affect public service with regard to plant replacement?

Dr. FREDERICK. Probably the roll-back provisions of the bill are the ones that would most affect us.

Senator HUMPHREY. Do you know how that would affect the industry? Can you speak on an industrywide basis? Would you agree with the Sierra Club?

Dr. FREDERICK. I know that it does affect some utilities.

Senator HUMPHREY. Has the Sierra Club endorsed any formula of cost sharing?

Ms. HAM. No. The Sierra Club hasn't endorsed formally any formula for cost sharing. The main reason for that is that we feel that we are not expert enough in the economic field to come up with a plan that is meaningful. The two things certainly aren't opposed to a cost sharing program. In fact, in general we favor one, but it does have to be equitable regionally speaking. It does have to address the inequality of regions we now have.

Senator HUMPHREY. Ms. Tuxill, in your statement you made the point that precipitation in New Hampshire is 40 times more acid than normal. What are you using as normal in your statement?

Ms. TUXILL. That's pH 5.6, the level that is normally accepted.

Senator HUMPHREY. Normally speaking.

Ms. TUXILL. Yes.

Senator HUMPHREY. Is that typical to the Northeast? Is that a national standard or regional standard of normalcy?

Ms. TUXILL. It's my understanding that that is the pH used whenever it's discussed.

I was just going to point out that the pH scale is logarithmic, so that when we are talking about going from 5.6 to 4, it is more than just a normal progression.

Senator HUMPHREY. Yes; I undsrstand. Just for the record, because frankly I agree with you on this point, why do you find the rumored four-State program to be totally unacceptable?

Ms. TUXILL. Because I don't think—from my reading, it is aimed at the Adirondacks. That's what we are talking about. And I don't feel that it's going to really make the type of changes that we need in New Hampshire with respect to acid rain. And I think rather than going for a smaller trial-type program, I think we have a significant body of scientific evidence that supports a much broader program. And I think that it is the willingness of many of the citizens in many of the affected areas to help with cost sharing. I think that the cost question is not insurmountable.

I would like—with respect to costs, I would like to point out that there is one example of a 50-percent reduction program that has been put into place, and this is TVA in the Tennessee-Kentucky area. They put that into effect, and it's my understanding that the increase in rates in the most expensive year was a 6- to 8-percent increase. So that is an example of a 50-percent reduction in the program being put into effect.

Senator HUMPHREY. That's an interesting observation. It happens that TVA is under the jurisdiction of the subcommittee which I chair, the Subcommittee on Regional and Community Development. And your statement gave me an idea for a hearing.

What about cost sharing; do you have any thoughts on that?

Ms. TUXILL. Again, I don't consider myself an economic strategist.

Senator HUMPHREY. That makes you well qualified, I guess.

Ms. TUXILL. The problems are complex enough that the task force is not ready to put forth its own program at this point. But I would just reiterate again the strong feeling that we have that we would like to see an effective program, a 50-percent program, if we are asked to help pay for the costs.

Senator HUMPHREY. All right. Let me thank each member of our panel for their patience and help in this hearing today.

Our next panel, if they will come forward and haven't died of hunger by this point: Mr. Dennis Lunderville, Mr. J. Willcox Brown, Dr. Ronald E. Towne, and Mr. Richard Valentinetti.

Before we come to the third panel, I want to take a moment to ackknowledge the substantial help in putting together this hearing made by two members of the Senate Committee on Environment and Public Works staff who have had to just leave us in order to catch an airplane. They didn't know I was going to be so poky. They are Curtis Moore and Martha Pope who were seated at the front.

I will also point out that this committee will hold more hearings in Washington in the near future with regard to acid rain.

I also want to acknowledge the assistance of Tom Burack of my staff who handles environmental matters, who is a resident of Jackson, N.H., who is seated here at my right.

In the order listed on the agenda, we will take testimony now from Mr. Dennis Lunderville, director of the New Hampshire Air Resources Agency.

STATEMENT OF DENNIS LUNDERVILLE, DIRECTOR, NEW HAMPSHIRE AIR RESOURCES AGENCY

Mr. **Lunderville.** Thank you, Mr. Chairman. My name is Dennis Lunderville, director of the New Hampshire Air Resources Agency and chairman of the New Hampshire Acid Rain Coordinating Committee. My testimony this morning will emphasize those responsibilities as they relate to the impacts of acid rain on New Hampshire.

The New Hampshire Acid Rain Coordinating Committee was established by executive order in April 1980. Its purpose was to coordinate further studies into possible causes of increased acidity in New Hampshire lakes and the effects of acid rain, to represent the State at national and international conferences, and to coordinate the efforts of State agencies dealing with acid rain and its potential effects on the New Hampshire environment. Members of the committee are comprised of representatives of various resource agencies, the office of attorney general and house and senate committees.

In February 1981 the committee prepared a paper entitled "The Acid Rain Problem in New Hampshire" for the New Hampshire congressional delegation. This paper outlined the acid rain research conducted in the State and the specific research needs to better understand the effects of acid rain. The paper further outlined feasible solutions to reduce emissions of sulfur and nitrous oxides. New Hampshire sulfur dioxide emissions are approximately one-sixth of the total generated by New England, Ohio emissions are 5 times greater than New England and Midwest emissions are 15 times more than New England.

In May 1983 the committee, through the efforts of Dr. Peter Allen, prepared another paper entitled, "Acid Rain: The Impacts on New Hampshire." Copies of this report are entered as part of the hearing record. (See p. 305.) This paper documented acid rain impacts on New Hampshire and discusses less well documented but important concerns. Well documented effects are: damage to aquatic systems, visibility, water supplies, and urban runoff. The potential of impacts of acid rain in New Hampshire should serve as a warning to the State that New Hampshire's public perception as being a clean, healthy place to live, work and play is being threatened and that recreation and tourism, the second largest industry in the State, could decline.

It is the purpose and intent of this committee to encourage further research and investigation in the area of less well documented effects, and to make the citizens of the State aware as to the potential damage that results from acid rain.

The air resources agency and the coordinating committee have worked very closely with the New Hampshire congressional delegation on the acid rain issue.

You, Senator Humphrey, have supplied the agency with a wealth of information so that we could evaluate and respond to various questions and concerns relative to this issue. It is our intent to keep this line of communication ongoing. The issue is very complex and difficult to resolve. I say this from my involvement on the technical staff to Governor Sununu's staff in formulating the National Governors Association proposals that have been released. Wallace Stickney of Governor Sununu's office made a valiant attempt to formulate a staff proposal acceptable to those States on the acid rain task force of the NGA. The language of that proposal did in fact call for 10 million ton reduction of sulfur dioxide over two phases—a goal which you see as being essential. However, the reductions were not acceptable to the entire task force. I encourage you and your committee to pursue the necessary reduction to abate the acid rain problem that we are experiencing in New Hampshire and the Northeast.

In closing, acid deposition is a critical air pollution and environmental issue. Evidence presented has indicated that the State is, and will continue to experience environmental degredation unless the issue is properly addressed. Congress serves as the vehicle to do just that. I know it will be extremely difficult and the battle lines bloody, but you have our support.

I will be most willing to answer any questions. Thank you.

Senator HUMPHREY. Thank you. I hope we can skip the bloody part. I think we can.

Mr. J. Willcox Brown, chairman of the New Hampshire Water Supply and Pollution Control Commission.

Mr. BROWN. Thank you, Senator. If I had known your jacket was going to come off, mine would not have come back on.

Senator HUMPHREY. You are welcome to take it off.

STATEMENT OF J. WILCOX BROWN, CHAIRMAN, NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION

Mr. BROWN. Before starting the text, you made reference to an item that was raised previously regarding correspondence with Dr. Purl and others on the important questions of potential connections between aluminum mobilized and transported and Alzheimer's and other diseases. As a member of our staff who is here, Dr. Peter Allen, whose name was just mentioned by my colleague, has made an extensive effort through correspondence and through some travel to get all of that material, and I think you might like to have that. Peter is back here. I'm sure he can check with Tom afterward to see that you have that material.

Speaking of titles, the gentleman to my right is so flabbergasted by having been given an honorary doctorate, he may not allude to it. We all call him "D."

Dennis has given you a concise summary of the origin and development of the State acid rain coordinating committee. He has outlined the scope of the projects and the results to date.

I will summarize some regional activities related to these State efforts and possibly to some extent stimulated by our efforts in the State. The New England Interstate Water Pollution Control Commission has had more than 30 years of productive existence under an interstate compact. This compact had to be adopted by each New England State and New York and then ratified by Congress.

With the growth in complexity and severity of environmental issues, the interstate commission, NEIWPCC, as we affectionately call it, has also evolved. The major recent concerns of this interstate commission have focused on acid rain, ground water and hazardous waste especially as it may impinge on groundwater.

The Northeast States for Coordinated Air Use Management, familiarly known as Nescaum, I have to have it written out in front of me to know what that stands for, while of more recent origin, is an essential ally in the struggle to cope with the acid rain problem. Fortunately, both regional organizations have recognized this alliance and have joined in forming the New England Task Force on Atmospheric Deposition.

This task force is composed of an air expert and a water expert from each of the New England States and New York and also New Jersey, since the later is a Nescaum member. The initial thrust of the task force was to prepare what I will abbreviate as the Northeast damage report. It's got a much longer title, published in April 1981.

This report is an essential reference work that has been used on previous legislative occasions. One such was the hearing of the New England congressional caucus conducted by both of our Congressmen in Concord on April 26, 1982. It is my recollection that a substantial number of copies of the damage report have been circulated on Capitol Hill. If you should wish additional copies, we will be glad to see that they are provided by the NEIWPCC office in Boston. Let me know if you want any; certainly 25, perhaps more than that would be helpful.

Senator HUMPHREY. We could certainly use one today if you could spare it. Thank you.

Mr. BROWN. Also, I am submitting herewith copies of the synopsis of the summary sections from the damage report. (See p. 316.) We have found that is much easier to handle, it gives page references for the full text on each subject. So we have distributed that fairly widely, too.

An item that is not incorporated in my text should be included. I have been trying to figure out a way to incorporate the word "significant" in my presentation. I don't think I had it in before. Another significant regional study has been undertaken by the New England Waterworks Association to determine the impact of acid rain on municipal water supplies. The initial findings are that acidity has potential severe effects, particularly health threats from corrosion of the system, not to mention very substantial economic penalties for repair of systems that deteriorate prematurely and for sweetening the water supply so that the corrosive effects can be reduced. Definitive results of that study are awaited, and thus I do have more information on it here, not a great deal.

The New England Governors for some years have had an annual joint meeting with the Premiers of the five eastern Canadian Provinces. The 1981 meeting in Newfoundland called for a report on the acid rain problem to be submitted at the 1982 Conference of the New England Governors and Eastern Canadian Premiers in Maine. It was my privilege to serve on the binational environmental committee that was responsible for developing this report. This document entitled "Acid Precipitation and the Long Range Transport of Air Pollutants in Eastern Canada and New England" reached final draft form in June 1982. If the committee should wish to have 25 copies, we will see that they are provided from the office of the New England Governors' Conference in Boston. Charlie Fossold, Tom, would be the one that would have those readily available for you, if you wish. It's—to some extent it's a further development from the Northeast damage report. There is some degree of duplication, also some further development of it.

Merely developing a report called for considerably more complex interplay than would prevail at the New England regional level alone. In fact, up until the evening before the conference began we wondered if we would be able to accommodate all viewpoints. Governor Snelling offered a resolution during the meeting the next day which achieved this objective. It is interesting that the diversity of views among the Canadian participants was more substantial than that on our side of the border.

A year later the report to the Governor and Premiers was updated based on the reports of the working groups of the Canadian/American Memorandum of Understanding; the initial phase of the treaty negotiation. It was found that only slight modifications had to be made from the report of the previous year. The meeting held in June of 1983 at Prince Edward Island resulted in the adoption of the resolution on acid rain which I am submitting herewith for the record. The key points in the resolution are as follows:

First, that the Governors and Premiers, and I quote, "called for reductions of acid precipitation precursor emissions in order to work actively towards a target loading of no more than 20 kilograms per hectare per year of wet sulfate in precipitation in New England and Eastern Canada." And the following ones are all basically quoted, too, as indicated. I have got to confess, though, I am so old fashioned that I still measure acres with a 66-foot line. When it comes to kilograms and hectares, I'm lost. I have asked one of my good friends how to translate that. It comes out to 18 pounds per acre at the same figure because of the differential between hectares and acres and kilograms and pounds.

Second, they called for Federal action and financial support to develop and demonstrate cost-effective retrofit technologies for emissions control; in other words, the limits on these other important things, I believe you are pushing them to work on now, in addition to applying currently available abatement technologies.

Third, they called for the development of a long-range energy policy for Eastern North America which considers the impact of future increases in energy demand on pollutant emissions levels. And that strikes me as a very sensible long-range way of going about it. You don't always see that in this type of resolution.

Fourth, they stress the urgency and necessity—that is where their role as a binational group is particularly significant—the urgency and necessity for our national governments to make all the efforts required in order to reach a mutually acceptable transboundary international accord clearly in the binational interest. And they urge the respective Federal Governments now to fully accept their responsibilities to each agreement in this area.

And their final point was just that they wanted this to be an ongoing effort; they wanted the heads of the environment at the next meeting.

And also in the transboundary Canadian area that there is a strong and increasing unified determination to work toward acid rain control with all deliberate speed. We trust that this situation will be supportive of your efforts in the U.S. Senate. Thank you very much for the opportunity to present these views.

Senator HUMPHREY. Thank you, Will.

Dr. Ronald E. Towne, New Hampshire Water Supply and Pollution Control Commission. Do you have a statement, Doctor?

STATEMENT OF RONALD E. TOWNE, CHIEF AQUATIC BIOLOGIST, NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION

Mr. TOWNE. Yes, Senator, I would indeed like to make a statement. It isn't doctor. I was flattered, but undeserving.

Senator HUMPHREY. You had us convinced. We put it on your name tag.

Mr. TOWNE. Speak authoritatively is the lesson here this afternoon.

I would like to present you with some information on what I have entitled "Acid Vulnerability," and to put some specifics into it.

Tailoring a surveillance program to keep a finger on the pulse of a suspected human health menace, to remain within an austere budget and yet conform to the constraints of timeliness has taken this shape here in New Hampshire.

We have monitored the storms for a continuum of over 11 years, and they are alarmingly acid—pH 4. We have appraised our remote alpine lakes, and many are acid—pickled—pH less than 5. Alkalinity determinations have been extremely low and vulnerabilty was commensurately high. Ionic aluminum, as an index of other metals present in the waters, was high. We feel we have reason to be concerned as to what threat this poses to human health and well-being; particularly certain dementias.

Transparency in our lakes and ponds has increased over a period of 45 years, implying a reduction in the living-broth we call plankton. Annual areal sulfate loading from atmospheric transport exceeds the accepted danger point. Recruitment among our wild animal populations appears to be in jeopardy. And, canvassing the man in the street, by way of an article in the warrant of each town's annual town meeting, we find a very strong mandate for the preservation of air, land and water quality.

Now, using the abstract as a skeleton, I would like to flesh it out a little bit with some further remarks, but that is the gist of what I would like you to be aware of.

I gave this a banner when I wrote it out, as I quote from Shakespeare's Richard III, which says, "Devouring pestilence hangs in our air."

The longstanding boast in New Hampshire is that it is the "Granite State," and so it is: but this well may be its eventual undoing—its Achilles heel. New Hampshire stands along the northern bastion of the primeval Appalachian range: igneous in origin, crystalline in structure, and among the oldest mountains in the world. Crystalline rock weathers slowly, makes an acidic soil because of its dearth of buffers, is high in metails and radioactive materials; and is extremely vulnerable to acid inputs.

About all that our limited capabilities here will allow us to do is to document what we choose to call the impending disaster. We consider ourselves to be like Plimsol lines on British hulls, we register how much further we can sink.

Now, we believe we have the second longest record of precipitation chemistry in North America; second only to the one at Hubbard Brook U.S. Forest Experiment Station, upon which you have heard Dr. Hornbeck expound. The true average pH for this 11-plus year continuum is 3.973, in essence 4. Because pH's are not true numbers, these are expressions of exponential values, they can't be averaged. What we did is put them into microequivalents and averaged them out to get this figure of 3.973. We put the 11-year continuum through and drew out the number, which is 4, we feel. We consider this to be much more appreciably more acidic than the mathematically determined pH of 5.65, which you, sir, were questioning Mrs. Tuxill about. This is the mathematically determined figure from the ordinary carbon dioxides that occur naturally in the atmosphere. Combined with water, it works out to this particular pH. The water that fell on the Indians was slightly acidic.

Acids are employed chemically to dissolve metals, and pH 4 will mobilize most of the metals that exist as inclusions in the soil. Over the last 3 years, we have recorded only three storms with a pH above 5, and the most recent one of those was in December of 1981. In passing, we should mention last night's storm was pH 3.5, which is an unfair comparison to orange juice. The pH's are the same, that's about it. Orange juice is a relatively mild organic acid. What we are being delivered is dilute mineral acids, and the ionic potential in here is tremendously greater. All they have in common is pH. We try to put this in terms that people can equate with. Last night's was 3.5.

Now, in our monitoring, we determined aluminum concentration in the lake water, as an index of the metals present, and we find concentrations as high as 360 micrograms per liter. Aluminum in rain water is below our limit of detection. Aluminum does exist as an inclusion in air masses, but it is measured in nanograms per cubic meter, which is thousandths of a microgram. So we feel that contained metals did not come from that source, from the air. Some of our lakes are water supply reservoirs; and, although no maximum allowable standard has been established for aluminum in drinking water, the American Public Health Association recommends a limit of 500 micrograms per liter for residual aluminum as it leaves that because many of your water treatment plants use aluminum sulfate as a block. So the pH must be adjusted and aluminum reduced to this point; at least that is the recommendation, although no study exists.

Now, the history of civilization is probably the history of disease. And on that premise, we worry about the unknowns in the role of aluminum in certain types of senile dementias, which Dr. Wallace has already mentioned. Aluminum, with a valence of 3 and a coordination number of 6, forms extremely firm attachments that do not permit its removal by any biological means. Now, is excess aluminum in the nucleus of the cells of the hippocampus region of the brain the agent that destroys memory? Is this the underlying factor in Alzheimer's disease?—in dialysis dementia? Does elevated blood aluminum cause hyperactivity in children? There are some who say, "Yes," to all of these. If so, what species of aluminum is damaging? Aluminum changes speciation with pH. Above pH 5.5, in fact, aluminum becomes a buffer.

Now, New Hampshire is third from the top, nationally, in the number of cases of Alzheimer's disease reported each year. Rhode Island is first.

In most parts of the world, alkalinities of less than 200 microequivalents are considered as being nonexistent. We have noticed that where even small amounts of buffer exist in standing water, the pH will be maintained. It's not until a pond exhausts its alkalinity that the pH will be depressed below the 5 mark: that's when the great big, slow motion, natural titration reaches its end point.

In May of 1983, as in previous years, our agency has accompanied the State fish and game department during their annual, late spring stocking of remote mountain tarns by helicopter. Of the 36 ponds examined, 35 had alkalinities of less than 200 microequivalents: with commensurately low pH's and high aluminum. The median aluminum was 45 micrograms per liter maximum with 290.

Now, we are told that ponds with sulfate loadings from precipitation of 20 to 30 kilograms per hectare, that's about 2½ acres, per year show evidence of chemical alteration and acidification, including fish kills. And those receiving more than 30 kilograms suffer long-term losses.

Well, using our median sulfate level for precipitation of 3.6 micrograms per liter, and an annual rainfall of 45 inches, New Hampshire's annual sulfate loading is 41 kilograms per hectare. And this does not include the dry fall. Something is coming down today.

As elevation increases, so does rainfall. It rains more up there. Many of our alpine lakes receive 50 or more inches of precipitation per year; much of it in the form of fog, mists and hoar frost, which, as you have heard today, may be three to five times as acidic as rain or snow.

Now, acid rain in New Hampshire raises questions about the effect upon wildlife:

Why has the adult female deer incidence of pregnancy declined from 95 percent to 77 percent? These are figures from last fall, 1982. Something is happening to recruitment

Acid rain leaches already scarce elements out of the soil. What impact does the loss of selenium have upon wildlife, particularly in this white muscle disease?

Acidic deposition may affect mammals by causing changes in the soil chemistry that can sequester important nutrients. The solubility of selenium in the soil or water declines with pH, and the uptake by grasses is inhibited by sulfur dioxide, so concentrations of selenium in forages are low receiving acidic deposition. Furthermore, excess sulfur in the diet of mammals can concentrate selenium many times. A dietary deficiency of selenium leads to degeneration of the liver, kidney, and heart, muscular dystrophy and white muscle disease. Many soils in eastern North America are naturally low in selenium. They produce forages with concentrations below one-tenth per part, which is recognized as essential.

Does the uptake of metals by plants have any effect on the browsers?

Does the acidification of our waters reduce the productivity to such an extent as to reduce the food supplies of those animals that are keyed to the aquatic and wetland environment, the tree swallow, moose, waterfowl, woodcock and furbearers, and the like?

Wildlife declines are regionwide. The deer kill of last autumn was down in all Northeastern States and provinces. These events need study. Funding and manpower constraints in our resources agencies are such as to make such investigations impossible. These are regional problems that should be funded equitably and studied regionally.

The town meeting plebiscite has been well explained to you by Jackie Tuxill. I would like to give you just these final comments; sort of my Carthian shot while retreating at full gallop.

For us in New Hampshire the long-range transport of air pollutants, or acid rain, has become a spectator game. We are an observer, not a player. The issue has long since graduated from the scientific to the political arena.

Yet, regardless of how vaid one considers the data, or the seriousness of the consequences, there can be no denial of the diplomatic seriousness. The final decision will be based on subjective judgments in an imperfect world. And thank you, sir.

Senator HUMPHREY. Thank you, Dr. Towne.

[Whereupon there is a 5-minute recess.]

Senator HUMPHREY. The last witness on this final panel is Mr. Richard Valentinetti, director, air and solid waste program, agency of environmental conservation of the State of Vermont. Mr. Valentinetti.

STATEMENT OF RICHARD VALENTINETTI, DIRECTOR, AIR AND SOLID WASTE PROGRAM, AGENCY OF ENVIRONMENTAL CONSERVATION, STATE OF VERMONT

Mr. VALENTINETTI. Thank you, Senator. I'm reading a statement that was prepared for Secretary Brendan Whittaker of the agency of environmental conservation who expressed his regrets in not being able to attend himself.

Senator HUMPHREY. Fine. Might I ask that you hit its highlights.

Mr. VALENTINETTI. I certainly am. That was my planned intention.

Senator HUMPHREY. That's for your own safety.

Mr. VALENTINETTI. Basically, the agency of environmental conservation appeared before the committee when Senator Stafford had some hearings in Vermont 2 years ago. And at that time the agency did not have much hard data on what was happening to our waters and air. And in that intervening 2-year period, we have received a lot of data, and basically it really gets down to the fact—and that data is outlined in the testimony. It basically gets down to the fact that everywhere we look, the damages and potential damages are not less serious but more serious and more widespread than we had anticipated; and that our recent research confirms that these damages are resulting from distant manmade sources and from Midwest coal burning, in particular.

Rather than going into a dissertation on what is happening on the waters, since we have heard much testimony on that already, what I would like to touch upon is an area that hasn't been touched upon in much testimony, and deals with the visibility issue.

One effort that we did during this past summer was to take visibility readings and also sulfate readings. We made some correlations on those. The results were based upon observations taken at the airport in Burlington, Vt. The results indicate that during nonrainy, nonfoggy periods, about 90 percent of the time, the combined effect of sulfates and relative humidity account for 87 percent of the variation of light extinction in the atmosphere. This was based on congressional analysis. And that sulfate alone accounts for 84 percent of this extinction. To put it into perspective so that it's somewhat simpler to understand, what it really gets down to is the average visual range at the Burlington Airport is about 22½ miles. Had there been no sulfate in the air, it would be close to 33 miles; actually, a decrease—an increase of approximately 25 percent. On July 17, 1983, we had our highest sulfate readings. They turned out to be about 35 micrograms per cubic meter. At that time the visibility dropped to less than 5 miles.

The sulfate samples that were collected were done at the Proctor Maple Research Center in Underhill, Vt., as part of a larger cooperative study between our agency and Dr. Kenneth Rahn of the University of Rhode Island. Dr. Rahn, as you may recall, was among the first to suggest the importance of local sources impacting on sulfate concentrations in the Northeast. His earlier work was based on the ratio of manganese to vanadium in the air near Narragansett, R.I., and compared these ratios to—of these elements from different regions. He has now expanded that work to include seven elements, and with these he is able to distinguish the aerosols originating from six different regions of North America.

What is interesting is that we have been cooperating in sending him samples of our sulfates from our Underhill station, and he has done further analysis to look at those elemental chemicals. What we are finding is that during 1982, that up in Underhill, Vt., that 40 percent of the time the sulfates were from New England sources. However, it was generally a sulfate free air, around a concentration of 3 micrograms per cubic meter. When we look at the data and see the distinct Midwestern coal burning signature, what is happening is that although it's only 25 percent of the time that we can make that connection, it is at 21 micrograms per cubic meter, seven times the sulfate concentration associated with the local New England signature. I think that is very critical in looking at the whole question of visibility.

I think the other thing that is happening is the continuing work on Camels Hump. In the intervening years, much has occurred. You have heard the testimony from Dr. Klein this morning, and Dr. Vogglemann and he have done some tremendous research on that mountain. Basically it does seem to confirm their earlier suspicions that the combined effect of acid rain and certain metals may in fact be an important causal factor in the decline of these high elevation forests.

In the request for testimony, there was some indication that you were looking for what should be the number. I think that you heard an awful lot of testimony on that issue earlier, and I think that all of the people from the professional community agree with that number, too; and that is, that it should be in the range of 10 million to 12 million tons reduction in the eastern portion of the country.

I think that the National Academy of Sciences in their two studies, both which have shown that a 50-percent reduction would be needed, 10 million to 12 million tons; and the question of linearity of that reduction and the effect on the environment are important issues.

Also, there has been some questions raised about who is going to pay for the controls as far as acid rain. Will Brown mentioned the efforts between the Premiers and the Governors. In a separate meeting that was also held at Prince Edward Island, the Governors passed a resolution in which they talked about the equitable sharing of that burden. And they were very precise that they were talking about equitable and not equal. But I think it's a recognition on the part of the New England political leaders that in fact in order to get this acid rain program off dead center, that there has to be some sharing the costs.

Governor Sununu talked about the national acid rain trust fund that they're discussing at the NGA and the possible combinations of that to in fact produce this equitable solution.

Those are my primary high points. What I do have is four slides, and I would like to show them now.

Everybody has been hearing about Camels Hump, here is a view of Camels Hump. What I'm trying to do is show you that we have some good integrated vistas in the State of Vermont, this was taken on July 14. What this is, is the ridge of Mount Mansfield. It's Mount Mansfield looking at Camels Hump, which is this mountain in the background. Way in the distance is Mount Ellen. And this is Mount Bolton. Mount Bolton is approximately 5 miles away, and Mount Ellen, those that may ski in Vermont, that's Sugarbush North's top mountain, is way up in the back here.

Now, the following day we had an increase in sulfur. The following day, July 15, sulfate concentrations began to climb, averaging 6 micrograms per cubic meter. The first day, there was no bronze signature and it was 1 microgram per cubic meter.

The Rahn analysis of this data indicated that 60 percent of the sulfates were from the Midwest region. Now, Camels Hump is just barely visible. This is Mount Bolton 5 miles away, and Mount Ellen is gone.

This is July 16. Sulfate concentrations are at 13 micrograms per cubic meter, 97 percent of which is associated with the Midwestern signature. Bolton Mountain now is just barely visible. You can't even see Camels Hump.

This is July 17. Sulfate concentration peaked at 35 micrograms per cubic meter. This is the highest sulfate concentration we had during the past summer. The Midwestern signature is one of the strongest that Dr. Rahn has seen. The only thing that is now visible is the mountain that we are standing on. This is the far ridge of Mount Mansfield, and you can't even see Mount Bolton, which is 5 miles away.

You asked earlier about dry deposition. This is dry deposition. This, as far as some of the air pollution people feel, may be more important than the wet issue of acid rain; maybe the question of what type of influence this is having not only on our visibility but also on our public health.

Dr. TOMLINSON. And our trees.

Mr. VALENTINETTI. And our trees. Thank you.

Senator HUMPHREY. Thank you. That was a very dramatic display. As a matter of fact, I'd like to copy those, if I might, and show them to the full committee. It would be nice to be able to correlate those with weather maps for each of those days to show the air flow.

Mr. VALENTINETTI. If you give me a little time, we will put that together and send it down to you, Senator.

Senator HUMPHREY. That would be a big help.

Mr. **Valentinetti.** And do nice 8 by 10's.

Senator **Humphrey.** That would be better than slides. They can take them home that way.

Dr. **Tomlinson.** Senator, when there is no rain, the sulfur dioxide goes somewhere, and this is what is lost track of, when we spend so much time talking about pH, because the SO_2 has to get somewhere and it does go into this form and onto leaves, onto people's lawns, and various other places.

Senator **Humphrey.** Were there five distinct signatures?

Mr. **Valentinetti.** Well, what Dr. Rahn has done is, he is able to come up with six different regional signatures from North America.

Senator **Humphrey.** North America, you say? Does that affect the Northeast?

Mr. **Valentinetti.** You may want to contact him directly and get some of his basic work. But basically he feels that he is able to distinguish the difference between Midwestern, New England, the idea of the smelters in Canada, and how that all impacts.

Senator **Humphrey.** Well, that is really some smoking-gun type of evidence, I think. What is the signature today? We had a cold front go through, I guess, this morning. We have a westerly flow. What are we breathing now?

Mr. **Valentinetti.** I don't know, Senator, it is a part of the weather pattern. I think it is reasonable to say, although not competely proven scientifically, that when we do have high haze and high relative humidity that you're experiencing some significant sulfate levels; that the sulfate does have a tendency of expanding within that high humidity. And so what we have thought about as just wet relative humidity now, as haze, we are seeing more and more evidence that there is a strong correlation between that haze and sulfur.

Senator **Humphrey.** You say that the sulfate expands during periods of high humidity. What do you mean by that?

Mr. **Valentinetti.** The sulfate is a particle, it's a dry particle that's moving across the air. When you reach a certain relative humidity, and I believe it's about 70 percent, it expands and it causes more light extinction.

Senator **Humphrey.** The particle?

Mr. **Valentinetti.** The particle expands.

Dr. **Tomlinson.** It picks up water.

Senator **Humphrey.** Yes.

Dr. **Towne.** Air is like a hot dog. You don't really want to know what's in it.

Senator **Humphrey.** No; that's legislation.

Mr. **Valentinetti.** Incidentally, on July 17, that night we had a rainfall and it was 125 times normal rainfall, it was the pH of orange juice, 3.5.

Senator **Humphrey.** What about vertical distribution? Has anyone studied that; is it worse closer to the ground, the concentration of these particles?

Dr. **Towne.** It has been studied. That's true.

Mr. **Valentinetti.** I think we get back to the work that's being done at Camels Hump. I think the whole question of what the Camels Hump does is it interacts that air layer at a high level, and what we are seeing is the effect of the cloud issue and everything else as far as its impact.

Senator **Humphrey**. Do we have any historical data that can be used for comparison?

Mr. **Valentinetti**. Well, we have airport visibility. You know how subjective that is.

Senator **Humphrey**. Yes, I do. Especially in Burlington.

Mr. **Valentinetti**. I think that's what we are trying to do right now in doing these studies, even though airport data may be subjective, it's subjective over a long period of time. There are points that are looked at. And, yes, we are going back and trying to make some correlation, although it has some fatal flaws in trying to determine what's happened over the past 40 years in the airport as far as visibility.

Senator **Humphrey**. This whole business of visibility is very interesting to me, particularly because of my background in aviation. It detracts so much from the beauty of nature when visibility goes to pot, which it does very fast. I've often wondered whether it's worse nowadays than it used to be. I always thought it was predominately humidity, the moisture particles that reduce the visibility. You are saying on a broad scale, it's also sulfate particles?

Mr. **Valentinetti**. I think that was a common perception 10 years ago, 15 years ago. It's only recently—and again, all of the science isn't in yet, but in an impurical point of view, when we have started to look at some of this stuff, it's—the theory is proving out as far as the acceleration of the light scattering potential above our relative humiditiy of 70 percent.

Senator **Humphrey**. Well, Dr. Towne, I think you were so thorough you left nothing unanswered.

Dr. **Towne**. There is one thing I would like to add.

Senator **Humphrey**. OK.

Dr. **Towne**. That is, we can't lose sight of the fact that 50 percent acidic as pH 4 is pH 4.3. And what builds in my mind, is that enough?

Mr. **Brown**. You want a 150-percent reduction?

Dr. **Towne**. If you reduce 90 percent of the acidity, you are still only at pH 5.

Mr. **Brown**. You need a few options around.

Dr. **Tomlinson**. I think it's important, Senator, that the equipment that is put in be equipment that can be very efficient, otherwise we may be like the old stack situation; put in a high stack and further down there will be no problem. It's accumulating in time and then it is a problem.

If we put in a lot of work on coal to take only 20 or 30 percent, spend our money that way, it may not be too productive. At least have whateverever done done sufficient and well.

Senator **Humphrey**. Dr. Towne, how do you fit into whatever you are?

Dr. **Towne**. I'm our chief aquatic biologist and cochairman of the technical advisory board to our acid rain coordinator.

Senator **Humphrey**. What about this matter of lead and copper leaching in water supplies? Is that a real problem in the State nowadays?

Dr. **Towne.** This question came up, and I don't, I think, feel right in interfering. There has been a study done by the New England Waterworks Association to address this very question that you raise: What is it doing? And Mr. Ferry, who was here, Clarence Ferry, was here this morning, had the information on that. I think he could probably provide better information that I could.

Senator **Humphrey.** We will solicit that. He mentioned to me that he had someting. We will try to get that.

Dr. **Towne.** That was done all through New England and I guess through New York and New Jersey and is being expanded now through the eastern seaboard, but he was the representative here from New Hampshire as the former superintendent of the Manchester Waterworks.

Mr. **Brown.** He sits on our coordinating committee. Clarence gave me an outline of how they are going to go after a report, if that's any help. It's not yet in final shape.

Senator **Humphrey.** Well, you have just finished a term as chairman of the New England Interstate Water Pollution Control Commission. Can you tell us what the state of agreement and disagreement is among the New England States on the issue of acid deposition?

Mr. **Brown.** A very high degree of agreement. It has initially, say, 3 years ago, varied somewhat depending on the vulnerability of the soils and the bedrock in given States. Southern New England is less threatened than we are; I think that's correct. The map shows very clearly that most of New Hampshire is highly vulnerable except for possibly a little strip on the upper Connecticut River where they get into the same sort of bedrock as over in the northeast kingdom of Vermont. Vermont is luckier than we are, I believe, Dick, you have substantial areas in the Champlain basin that are not as highly vulnerable; there is a little more calcareous material in there?

Mr. **Valentinetti.** That's right.

Mr. **Brown.** So we haven't started out with a uniform figure as far as our susceptibility is concerned, but as I have seen the sentiment and the conviction developed within the interstate commission, it's very nearly unanimous that we have a tremendous problem, much worse than we realize. The sooner that we can get far-reaching solutions, the better.

Senator **Humphrey.** Are there similar interstate commissions such as yours in other regions?

Mr. **Brown.** None that are directly comparable that I am aware of. There are, of course, regional commissions; for instance, the interstate sanitary commission that includes New York and New Jersey, which is centered right around that metropolitan area. But I don't know of any extensive regional commissions. We are lucky to have New York in with us because that brings a lot of political heft as well as broadening the area, and that's only because some of the watersheds overlap into the New York boundary.

Senator **Humphrey.** It might be useful for people in your area of expertise to talk to some of the midwesterners and others who understand your language. I think you could get to them more quickly because of a shared knowledge and shared basis.

Mr. **Brown.** One of our best approaches is at the national level and at the federations of people that work in this field, and that was where

Deke recently spoke. You developed some manuscript, didn't you for the—what is the correct title?

Dr. Towne. Water Pollution Control Federation.

Mr. Brown. A national federation?

Dr. Towne. Well, it's international, really. There were people there from India, Gema, and New Zealand and many from Canada. There are over 10,000 registered and I got away without being stoned, so I guess they listened.

Mr. Brown. Well, they had a meeting in New Hampshire several years ago—oh, no. It was the New England Federation of Water Pollution Control. And the national president of the federation that Deke spoke to just now was present. And we impressed on him the importance of this issue as we saw it. Perhaps that has something to do with your getting drugs down there.

Senator Humphrey. One last question. Bill, you are known foremost as a forester. What do you see as the implications for New Hampshire forests which, since they cover 80 percent of our land, are an important factor?

Mr. Brown. As a forester, I have been particularly eager to follow what was being developed in other areas especially Germany and Canada, the research at Camels Hump. I think that was so well presented today, there is no way I could top it except by a terrible simile that the tip of the iceberg is just barely rearing its head in the forests.

We are dealing with such—we are dealing with such an almost incredibly complex ecosystem in the natural forest that the buildup of threats and the circuitous route that they follow will almost surely cause results to be worse than we anticipated. And I think that that came out in Dr. Tomlinson's presentation and Dr. Klein's. I don't question at all that we are going to find out things that have been happening in New Hampshire that are just as severe as what Marcy Lyman alluded to and Dave Olson's presentation.

He has got some grafts of a 10-year growth rate in white pine, all of their sample pods very carefully calibrated, that show a decline in the rate of growth from about 2½-inch diameter rate to down to about six-tenths of an inch; that much drop within a 10-year period.

Well, even if you have no trees dying, that's very dramatic in terms of long-term forest management. We're not going to have anything to manage. Go in there once and cut and you have to wait 10 years for one-half inch of growth. I don't think it can be overemphasized, especially to a State that's so heavily dependent on timbering.

Senator Humphrey. Dennis, I congratulate the coordinating committee for its public efforts, principally the town warrant effort. I also want to take a moment to commend, unfortunately posthumously, Governor Gallen for setting up this committee in 1980. It has turned out to be an instrumental undertaking in this whole effort.

Where is the committee headed now?

Mr. Lunderville. At this point, I think the committee has presented to both the Governor of the State and congressional delegation the most recent data base that is available to us to support a need for emission reductions, a need to address the problem. The committee will continually address the recruitment of new findings that become available, share those findings, evaluate those findings, and hopefully be in a position to concur with those findings in a sense that they will provide further assurance that our efforts and your efforts are meritorious.

Senator HUMPHREY. A slightly different focus. In your capacity as chairman of the New Hampshire Air Resources Agency, can you tell us what progress we are making in the State in cleaning up emissions under the Clean Air Act?

Mr. LUNDERVILLE. The Clean Air Act of 1970?

Senator HUMPHREY. Yes.

Mr. LUNDERVILLE. As you are well aware of, the Clean Air Act of 1970 called for attainment of standards—quality air standards by 1975. Congress recognized that many areas were not attaining standards at that point. That served as a basis for the amendments in 1977. The States were required to develop new plans to bring those areas that were not attaining standards into attainment by a certain date, 1982, 1987. Up to this point, New Hampshire has several deficiencies in terms of areas not meeting standards; the greater Berlin area in particular. We have finally achieved a resolution on the ozone occident issue in terms of compliance schedules, and we expect that we would at least go forward toward trying to demonstrate attainment as New England and the east coast area will, but we recognize we have a long-range transport issue, very much as we have an acid rain situation; the problems are synonymous.

Carbon monoxide problems, we have one area in Nashua that we are trying to come up with a rectification plan to bring that area to attainment by 1987 or 1990, whichever we get a focus on.

Senator HUMPHREY. Very good.

Mr. BROWN. Senator, I'd like to leave with you a copy of a speech by the Canadian Minister of Environment. It does touch on this question of what they have committed themselves to do, and in view of the prior viewpoints expressed on Canadian relations, I think it would be informative.

Senator HUMPHREY. Excellent. We would be happy to have that.

Let me particularly thank this last panel for the patience of its members and endurance of hunger pains, I'm sure. It has been a very interesting and educational and helpful afternoon and morning, I believe.

Thank you very much. The meeting stands adjourned.

[Whereupon, at 2:10 p.m., the hearing was adjourned.]

[Material submitted for the record follows:]

DIE BACK OF FOREST TREES IN GERMANY AND THE ACID DEPOSITION LINKAGE

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Brief for Presentation at the Hearing of the
Environment and Public Works Committee
of the U.S. Senate

Concord, N.H.
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/sk

During recent years I have become very much concerned with the possible linkage between acid deposition and the die-back of forest trees now occurring in Central Europe and in certain mountain areas of Québec and of the North East U.S. Studies indicating such a linkage have been underway for many years in Germany where the situation is now viewed with considerable alarm. As a member of a committee which has met in Europe several times during the last few years I have had an excellent opportunity to review this European problem with several of the principal investigators, to participate in their workshops and field trips and to examine the problem at first hand. As other speakers will be discussing the parallel North American situation this morning I will concentrate on the situation in Central Europe.

Dr. Bernhard Ulrich and his associates and students at the University of Göttingen have carried out a particularly important series of experiments in the Solling district of Germany. They have established that sulfur dioxide present at low concentrations in the atmosphere is "dry deposited" and subsequently converted to sulfuric acid on the foliage and bark of trees. In addition, sulfate-containing aerosol particles which create atmospheric haze, and acid-containing fog and cloud droplets are also deposited on the canopy. During periodic episodes of rain the accumulated acid is washed from the canopy. Thus, the total amount of sulfate reaching the forest floor is markedly greater than that contained in the rain. They also observed that the soil, immediately adjacent to the fine roots, is substantially more acidic than a sample of the soil taken a short distance away, this resulting from a net transfer of a portion of the acidity received by the foliage to the fine roots and thence to the soil (1) (2) (3).

The average total deposition of acid on the Solling plateau of Germany during the period 1969 to 1981 was as shown in Table 1.

TABLE 1

Total Sulfur Deposited on the Soil

	kg S/ha/yr
In rain in open area	23.5
In "throughfall" and "stem-flow" under beech	51.0
In "throughfall" and "stem-flow" under spruce	87.0

The concentration of gaseous SO_2 at this location is in the range of 5 to 10 μ g/m^3 during the summer and 10-20 μ g/m^3 during the winter months, while on the average, fog is present during 71 days of the year. These and other data showed that as a result of wet, dry and interception deposition, the forest canopy with its large surface area acts as a major sink for air pollutants including unreacted SO_2, as well as that incorporated into aerosol particles, fog, cloud droplets and rain. The amount of sulfate picked up by the trees' canopies is highly dependent on their location in relation to sources of SO_2, the size and species of the trees and their exposure to prevailing winds, fog, and the quantity and acid content of the rain. Trees on mountain slopes subject to cloud impaction are particularly vulnerable. Conifers, with their jagged canopy profile and their year-round foliage, receive greater acidic inputs than the hardwoods as can be seen from Table 1.

Ulrich established that the acid entering the low pH soils of the Solling is dissolving aluminum from mineral substances such as clay which are present, while the sulfate inputs are leaching calcium and magnesium, nutrients required by the tree, from the rooting zone. Aluminum is also leached from the soil but due to its adsorption affinity for soil particles, which is greater than that of calcium and magnesium, it tends to displace the latter, with the result that the ratio of calcium to aluminum in the soil solution decreases as these acid-induced changes in the soil proceed. It has been established that the fine roots of the trees, necessary for the uptake of nutrients and water, become increasingly stunted and necrotic as this ratio decreases, with resultant "stress" in the tree. Fine roots will regrow under favourable conditions, but when regrowth does not occur the inadequate root system results in a drying out of the tree, a loss of the foliage necessary for photosynthesis, and in a reduction in growth rate. The trees thus become increasingly vulnerable to secondary stress from weather extremes such as frost or drought, insect attack, and other pollutants such as heavy metals and ozone.

Bauch (4), at the University of Hamburg has examined the root systems of forest trees in 11 districts of Germany. In soils with pH of about 7.0 at 30 cm depth the trees were healthy with good root systems, while in acid soils at pH of about 3.6 at the same depth the fine roots of both spruce and fir were seriously retarded, tree growth rate had slowed down or stopped, and the appearance of the tree showed heavy damage. Bauch found that the damaged trees showed no calcium or magnesium in the cells of the cortex (bark) of the fine roots whereas at higher pH these nutrient ions were both present. Calcium is an essential element for fine root growth and its absence can therefore be used as a diagnostic test for acid-induced stress. He established experimentally that aluminum ions will displace calcium from the cells of wood, indicating the probable explanation for ~~this~~ its absence in the fine root cortex.

In past years, only a portion of the atmospheric sulfate inputs to the soil has carried through the rooting zone in percolating water. The balance of the sulfate has been held in the soil as $AlOHSO_4$ which, as acidification proceeds, breaks down forming ~~sulfite~~ sulfate and aluminum ions with the former leaving the rooting zone at a faster rate than its rate of input. Figure 1 showing the change in storage of various ions in the soil over the period up to 1981, illustrates the increased rate of loss of calcium and magnesium that has resulted from the release of previously stored sulfate.

Changes in the storage of nitrogen in the soil can also result in a rapid loss of acid and nutrients from the soil. Acidic soils contain low stores of available calcium and magnesium.

In addition to the acid entering the soil from the atmosphere, nitric acid is also formed in the breakdown of protein present in humus and decaying wood. This nitric acid is normally reabsorbed through the tree roots for production of the protein required for the trees' growth. When nitric acid production and utilization are in balance there is no net change in acidity resulting from these reactions. However, nitric acid is formed from humus by the action of bacteria and fungi, populations of which are believed to increase dramatically with temperature. The quantity of nitrogen in the form of protein accumulated in the soil, particularly in northern climates, can amount to as much as one or several decades' supply, this being in equilibrium in any given ecosystem with the population of micro-organisms in the soil. Ulrich has found that the increase in soil temperature during a hot dry year can result in an "acid push", in which large amounts of nitric acid are formed. This is ultimately balanced by low nitric acid production at the lower soil temperatures occurring in cool moist years.

The following illustrates the effect resulting from the periodic temperature cycles that occur. In 1982 the soil temperature in the Solling in the period of June to

October averaged 11.5°C, an increase of 1.4°C over the same period in 1981 and the nitric acid concentration in the soil solution at 10 cm depth in September reached a value of approximately 55 mg/l as compared with about 5 mg/l the previous year as illustrated in Figure 2. This resulted in a serious loss of living fine roots of spruce. The concentration of aluminum ions in soil solution at 10 cm depth in September 1982 was approximately 9 mg/l, more than twice that at the same time the previous year.

Nitric acid in excess of that utilized for fertilizing the tree, is particularly serious with defective root systems, since this also moves through the soil and results in the leaching of calcium and magnesium ~~from the soil~~. Whereas die-back of trees as a result of soil temperature has occurred in the past, Ulrich has shown that this becomes particularly serious with each new warming trend because of the continuing loss of nutrients and of the buffer capacity of the soil resulting from the accumulated year-after-year atmospheric inputs of acid.

On the basis of his observations of the continuing changes occurring in the soil, Ulrich developed a hypothesis which suggested that, unless there is a major reduction in sulfur dioxide emissions, forest collapse, such as that which had occurred near major sources of SO_2 in the industrial Ruhr area of Germany and in Sudbury, Ontario could take place in many areas of Germany. Although this prediction was treated with skepticism by many, a serious change in the forests is in fact occurring at the present time.

In 1982, the German Federal Ministry of Food, Agriculture and Forests commissioned a study which established that 560,000 ha or 7.7% of the total forest area was showing die-back, and that the situation is changing at a serious rate. Figures 3 and 4 indicate the rapid change in the health status of fir and spruce respectively in the province of Baden Württemberg between the autumn of 1980 and the autumn of 1982. Table 2 shows the changes which have occurred in the Himmelkroner forest of Bavaria between April 1982 and March 1983. A study dealing with a 1983 forest survey of the whole country will be released later this year.

Figure 5 illustrates a map of Germany showing the major areas of damage reported in the 1982 survey, together with the pH of the soil and the sulfur dioxide concentration in the atmosphere. It will be noted that damage has been first observed in acidic soils having a pH of 3.0 to 3.5 similar to those showing stress in the North East U.S. The atmospheric SO_2 concentrations for 9 locations show average values in the range of 7 to 21 $\mu g/m^3$. These values are for the period 1973-1981 and were obtained from a monitoring network set up and operated by the German Federal Environment Office early in the 1970 decade. At that time no forest damage had been observed at SO_2 concentrations of 60 $\mu g/m^3$ and it was assumed that concentrations below the 60 $\mu g/m^3$ level would not have any deleterious effect on the forest. This was based on the previously held hypothesis that SO_2 damage resulted exclusively from its direct effect on foliage and ignored the combined effect of SO_2 and acid in rain, and the accumulative effect of total deposition on the soil, on the roots and ultimately on the tree itself.

In summary, the concept held early in the last decade that high stacks would dilute sulfur dioxide emission to a concentration below a threshold value at which no forest damage can occur has been shown to be invalid. In the same way neither the pH of rain nor the annual quantity of acid deposited in an open area can be used, by itself, as a criterion for the potential damage to the forest. German studies, conducted over a period of years, have shown that forest trees and their soils form a sink for sulfur emissions, regardless of their form, and thus ~~for~~ the total quantity of sulfur compounds deposited must be taken into account (5). In contrast to some earlier opinions, low pH soils, with their already low stores of calcium and magnesium have been found to be the most vulnerable to the effects of acid deposition.

NOTES

1. This brief summarizes and extends materials written by the author, and published in Environmental Science & Technology 17, pp. 246A-256A, June, 1983, under the title "Air Pollutants and Forest Decline". A copy of this paper is appended. The "box" on p. 249A summarizes the German Ministry 1982 report. References in the present brief not included in the attached articles are listed below.

2. All of the data from 1969-1979 obtained in the Solling forest ecosystem by Dr. Ulrich's group are published in Matzner et. al., "Elementflüsse in Waldökosystemen im Solling - Datendokumentation", Göttinger Bodenkunkliche Berichte, 71, 1982, (267 pages).

3. A compilation of various studies and conclusions of the Ulrich group, published under the authority of the German Federal Environment Offices of the Department of the Interior has been recently issued. Ulrich and Matzner, "Abiotische Folgewirkungen der weiträumigen Ausbreitung von Luftverunreinigungen", July 1983, (221 pages).

4. Bauch, J., "Biological Alterations in Stem and Roots of Pollution-Exposed Forest Trees" in "SO_2 und die Folgen" published by Gesellschaft für Strahlen- und Umweltforchung, Munich (translation available from G.H. Tomlinson).

5. Appended Figure ~~5~~ 6 is taken from a paper by Vaseduvan, C. and Clesceri, N., "Interrelationships Between Atmospheric Deposits and Forest~~t~~ed Watershed", paper presented at the AAAS Annual Meeting, Detroit, 29 to 31 May, 1983. This illustrates the effect of total deposition of sulfate in the open, on beech and on spruce trees. The deposition pattern is similar to that observed in the Solling, but at a lower level.

TABLE 2

DEVELOPMENT OF TREE DAMAGE IN HIMMELKRONER FOREST BAVARIA
300-400 m. elevation

	Date	Lightly Damaged 10-25% Foliage Loss	Damaged 25-50% Foliage Loss	Strong Damage More Than 50% Loss	Total Damaged
SPRUCE	Apr 1982	40%	-	-	40%
	Mar 1983	30%	50%	20%	100%
FIR	Apr 1982	-	50%	20%	70%
	Mar 1983	-	-	100%	100%
PINE	Apr 1982		None observed in 1982		0%
	Mar 1983	40%	15%	10%	100%
DOUGLAS FIR	Apr 1982		None observed in 1982		0%
	Mar 1983	30%	70%	-	100%

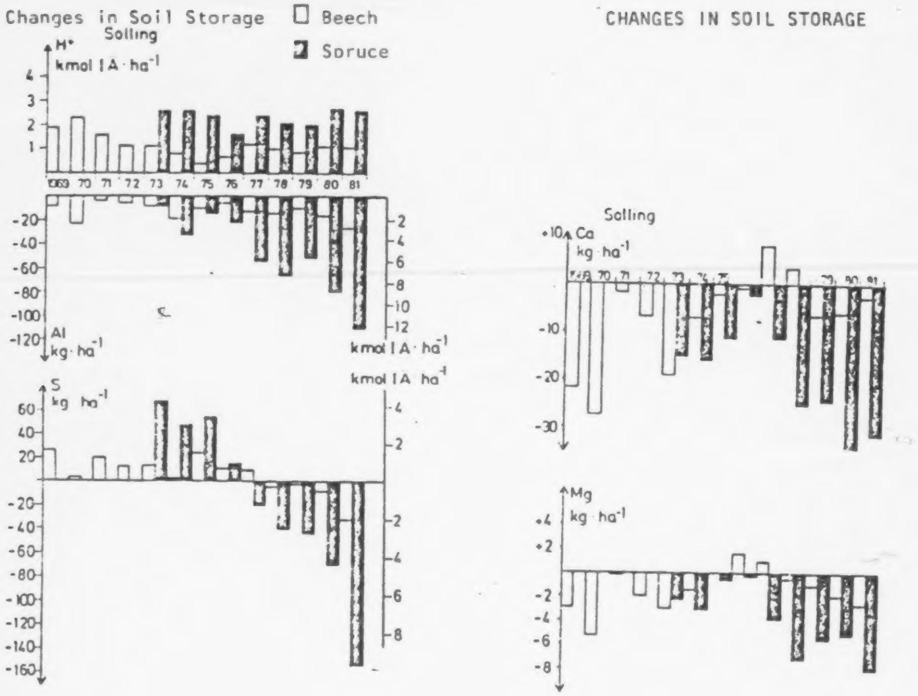

Changes in Soil Storage
Solling
Beech
Spruce
H⁺
kmol IA · ha⁻¹
4
3
2
1
1969 70 71 72 73 74 75 76 77 78 79 80 81
-20
-40
-60
-80
-100
-120
Al
kg · ha⁻¹
2
4
6
8
10
12
kmol IA · ha⁻¹
kmol IA ha⁻¹
S
kg ha⁻¹
60
40
20
-20
-40
-60
-80
-100
-120
-140
-160
4
2
2
4
6
8
CHANGES IN SOIL STORAGE
Solling
+10
Ca
kg · ha⁻¹
1969 70 71 72 73 74 75 79 80 81
-10
-20
-30
Mg
kg · ha⁻¹
+4
+2
-2
-4
-6
-8

FIG. 1

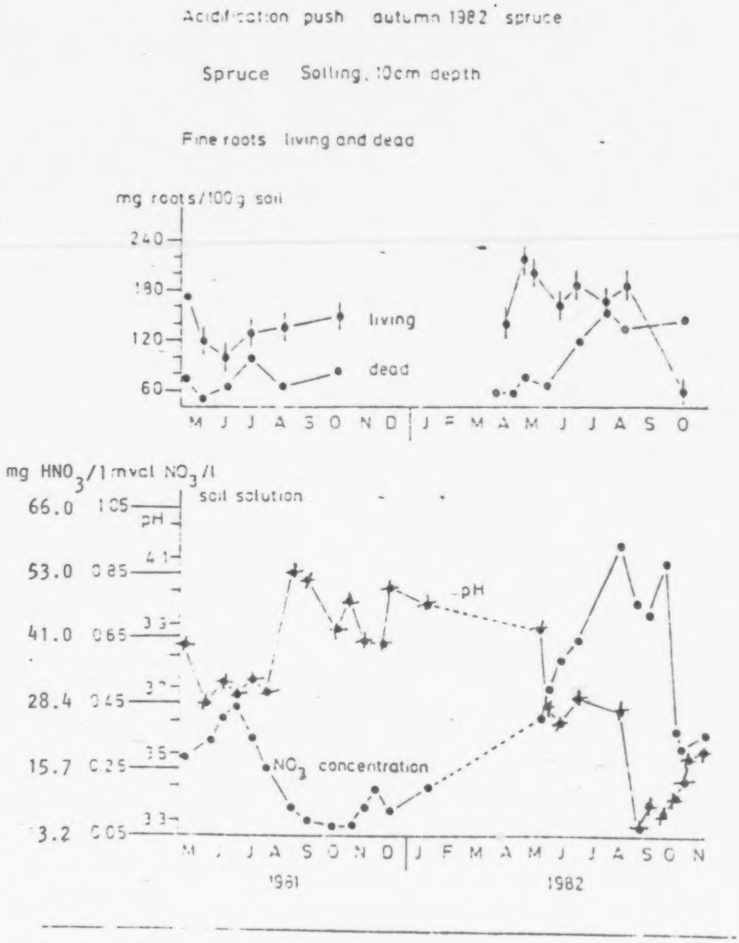

Acidification push autumn 1982 spruce
Spruce Solling, 10cm depth
Fine roots living and dead
mg roots/100g soil
240
180
120
60
living
dead
M J J A S O N D J F M A M J J A S O
mg HNO3/l mval NO3/l
soil solution
pH
66.0 1.05
53.0 0.85 4.1
41.0 0.65 3.9
28.4 0.45 3.7
15.7 0.25 3.5
3.2 0.05 3.3
pH
NO3 concentration
M J J A S O N D J F M A M J J A S O N
1981
1982

FIG. 2

TREE DAMAGE IN BADEN WURTTEMBERG - FIR
(includes Black Forest)

Gesundheitszustand der Tannen auf den Beobachtungsflächen

Health Status of Fir in the Observation Areas

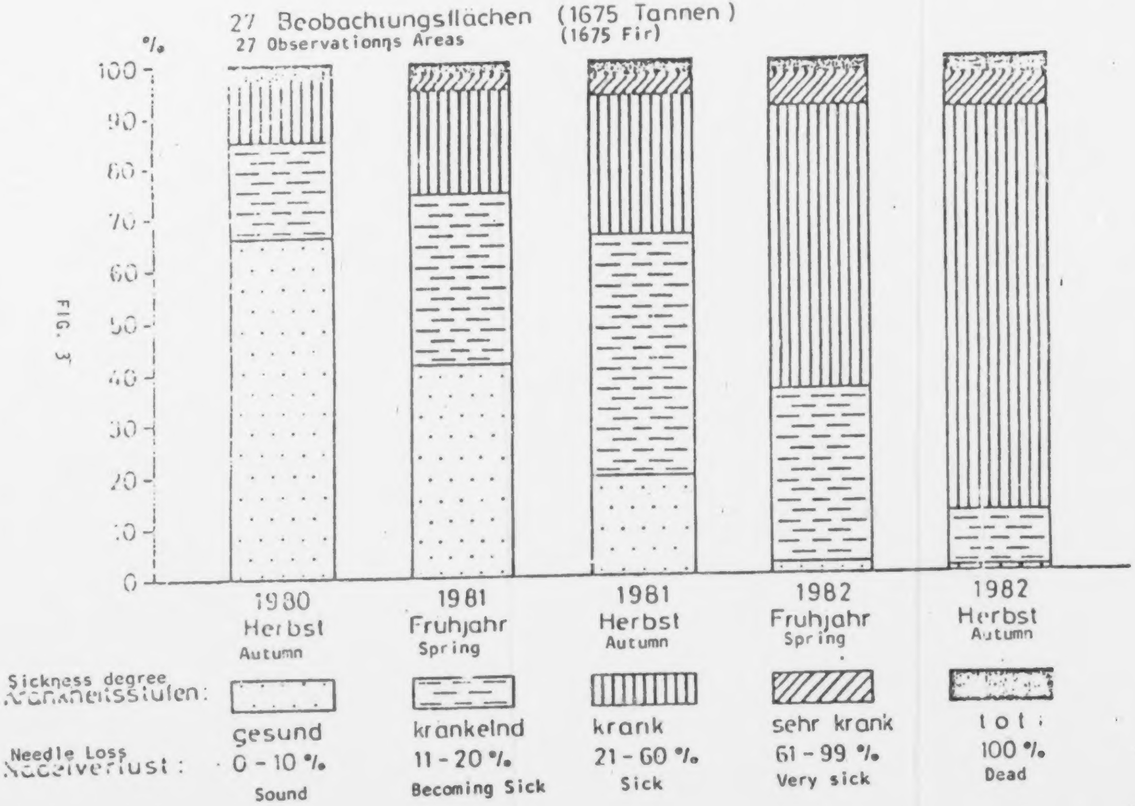


FIG. 3

TREE DAMAGE IN BADEN WÜRTTEMBURG - SPRUCE (includes Black Forest)

Gesundheitszustand der Fichten auf den Beobachtungsflächen

(Health Status of Spruce in the Observation Areas)

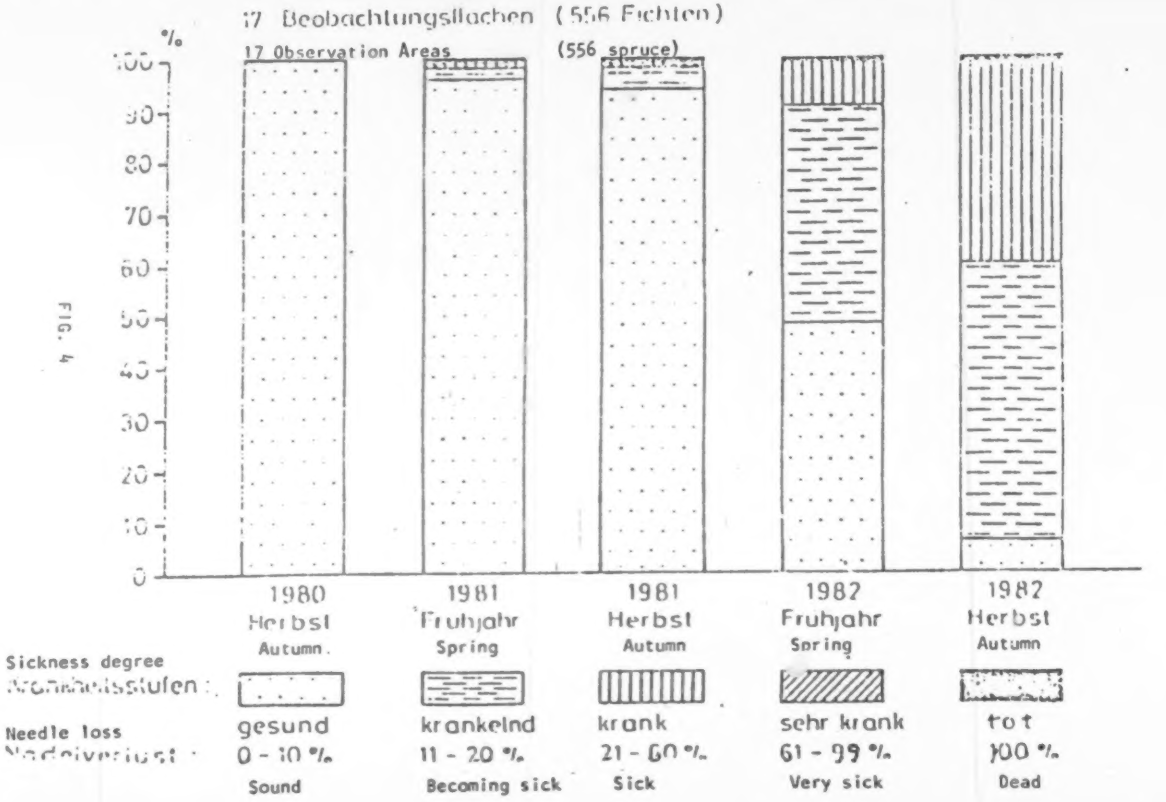
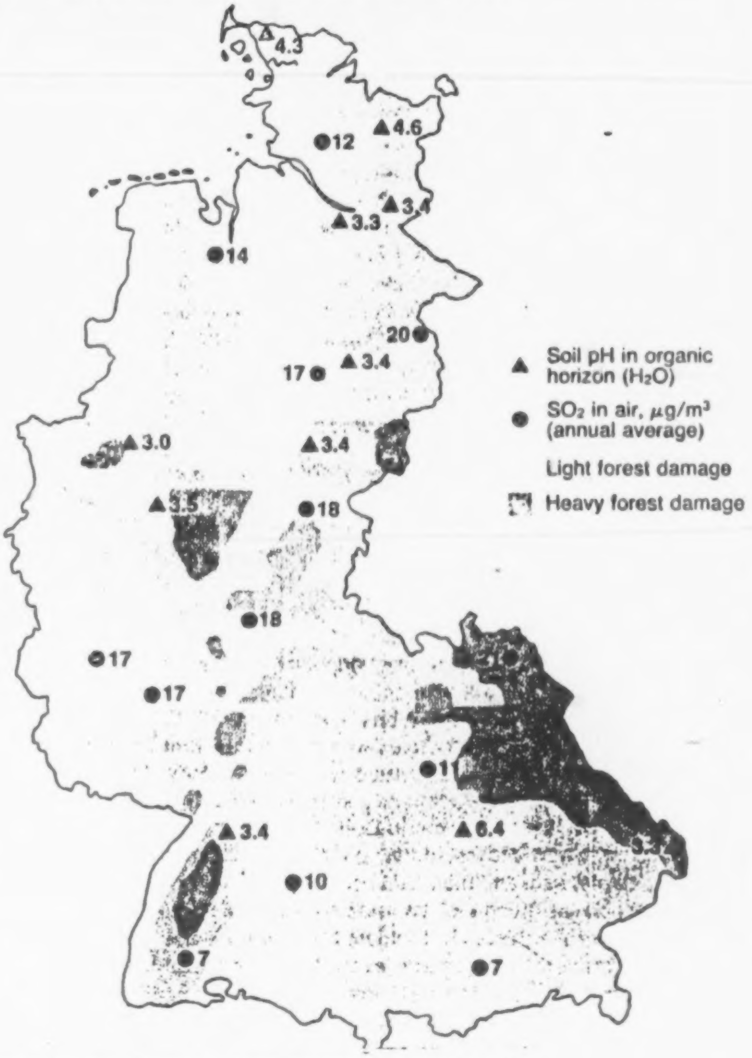


FIG. 4

FIGURE 1

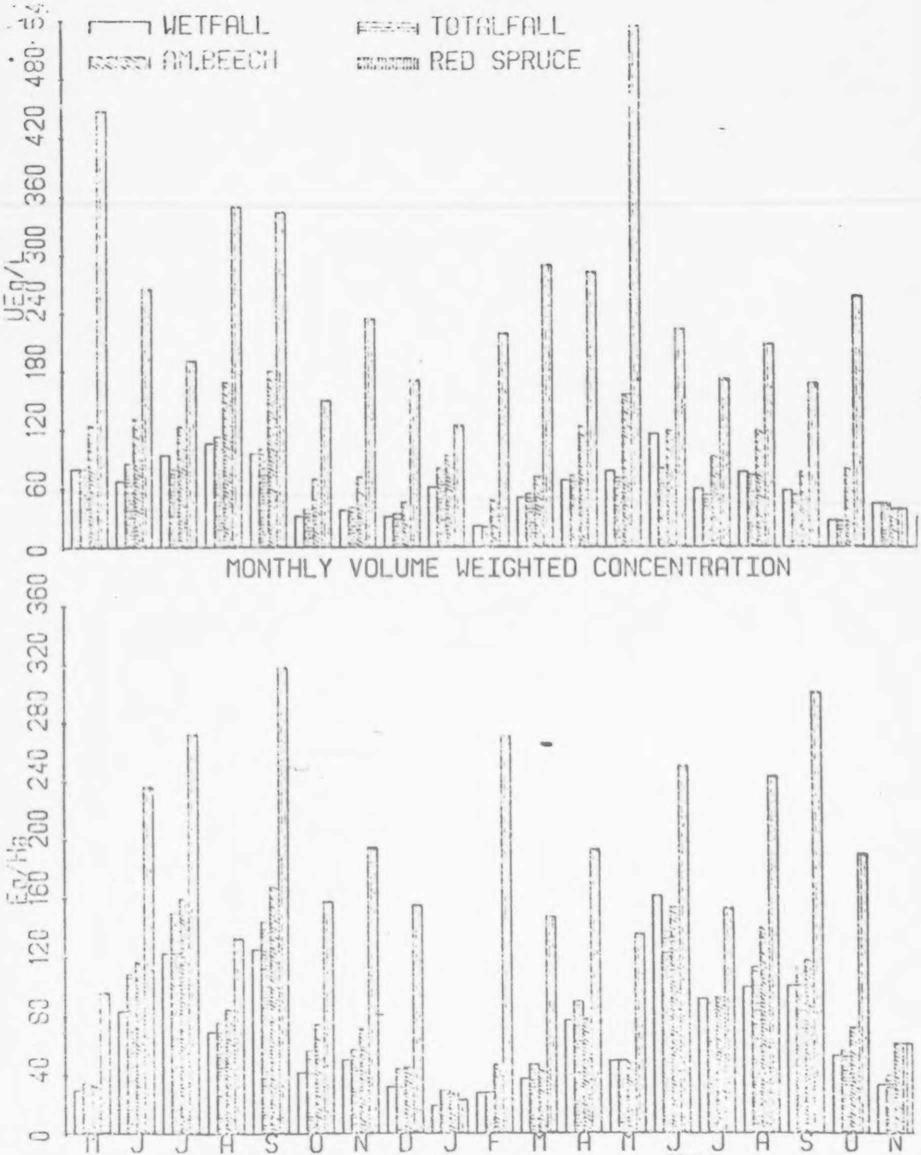
In general, the areas of forest damage in West Germany have acidic soil and relatively low concentrations of ambient SO_2[a]


4.3
4.6
12
3.4
3.3
14
20
17
3.4
3.0
3.4
3.5
18
18
17
17
11
3.4
6.4
3.3
10
7
7
▲ Soil pH in organic horizon (H_2O)
● SO_2 in air, $\mu g/m^3$ (annual average)
Light forest damage
▨ Heavy forest damage

[a] This does not include the forested areas immediately adjacent to strong SO_2 sources.

Source: Adapted from Stionen, H.; Rademacher, P. "Abiotische und biologische Aspekte des Waldsterbens," *Nat. Mus.* **1983**, *113* (6).

FIG. 5



MONTHLY LOADING

FIG. 6

Seasonal Variation of Sulfate Ion Input to Woods Lake Watershed (NY)

Statement of Elizabeth Ham
Representing Sierra Club
Before the Senate Environment and Public Works Committee
Concord, NH
October 14, 1983

In the past year it has become evident that acid rain is a particularly important issue for the residents of New Hampshire. When one considers that, on the average, our rains are forty times more acidic than normal, the reasons for this concern becomes more obvious. As a result of this high acidity five of our lakes are in grave danger of not being able to support life and many more are near this stage. Thus our tourist industry, which is based to a large extent on freshwater activities is threatened. New Hampshire residents considered the acid rain issue of great enough importance to pass an acid rain resolution, calling for a 50 precent reduction is sulfur dioxide emissions by 1990, in 197 towns at town meetings across New Hampshire.

Acid rain, however, is not just a New Hampshire problem. It is an environmental issue of national priority for it affects people's health and welfare and our nation's environment and economy. Across the nation reports of acid rain are increasing. In California acid fogs were reported to have a PH of nearly 3.0. The lakes of the Rocky Mountains have been reported to be very susceptible to acid rain. The Adirondack Region in New York State now contains over 200 bodies of water that can no longer support life. In Bennington, Vermont, the townspeople have had to buffer their water supply so that acid rain does not leach the toxic metal lead into their drinking water supply.

This problem requires immediate attention, for our lakes will not wait for us to decide when and how much to reduce emissions; they will continue to die. In its latest report, The National Academy of Sciences also calls for immediate action to stop acid rain. They warn that unless steps are taken now to reduce emissions the number of damaged lakes will double by 1990. They also estimate that acid rain is costing the eastern United States five billion dollars a year in damages. Therefore, the time has come to take action to stop acid rain.

Because acid rain is a national problem it must be solved at a national level by the passage of a bill through Congress. The passage of this bill must come quickly if we do not want to continue to threaten our lakes, forests, and river systems. The following are points Sierra Club feels should be included in any piece of acid rain legislation.

1. The National Academy of Sciences recommends that emissions of sulfur oxide should be reduced by at least 50 precent in order to achieve a PH level of 4.6 in sensitive areas. A PH of 4.6 has been determined by the National Academy of Sciences to be the level which no damages have been observed to date. This 50 precent reduction should be included in any acid rain bill.

2. The bill should include a cap on nitrogen and sulfur oxide emissions at the 1980 level.

3. Because of the need for immidiate action we believe a large precentage of these reductions should occur within the next five years. All reductions should be completed in the next ten years.

4. Nitrogen oxides should be reduced by 20 precent in order to ensure that in this national program the western states, which are affected most by nitrogen oxides, also have a reduction in acid rain.

5. There should be no trade off between reductions in nitrogen and sulfur oxide emissions. The National Academy of Sciences recommends that sulfur oxide emissions should be reduced by 50 precent. A reduction of any less than this,even if it is coupled with an increase in nitrogen oxide emissions reductions,will not stop the the damages being done by acid rain.

No bill introduced into Congress so far effectively addresses all five of these points. In order to achieve the reductions necessary to stop acid rain current legislation must be ammended or new legislation introduced.

In order to get strong legislation passed on the acid rain issue as quickly as possible the Sierra Club urges the New England delegation to unite behind one piece of legislation which includes the five points stated above.

SOCIETY
FOR THE
PROTECTION
OF
NEW HAMPSHIRE
FORESTS

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Testimony of
Paul O. Bofinger, President/Forester
Society for the Protection of New Hampshire Forests
before the
U.S.Senate
Committee on Environment and Public Works
October 14, 1983
Concord, NH

Thank you for the opportunity to comment on the need for a national program to reduce acid deposition and on the importance of such a program to New Hampshire.

Acid precipitation, for several reasons, is a national problem:

* While the Northeast emerged as the principal area effected by acid precipitation, many other areas including the upper Midwest, the Southeast and several western states are also victims of acid precipitation.

* In many cases the areas which are being effected cannot solve the problem by action at the state level. Federal action is required and the Clean Air Act is the logical and appropriate vehicle for solving the problem.

* And finally acid deposition is an international problem. It is estimated that half of Canada's acid precipitation originates in the United States. The problem therefore has become a foreign policy matter which requires federal action.

From a more parochial perspective, New Hampshire is one of the areas most sensitive to acid deposition. And yet, even if we eliminated all sources of SO 2 within the state we would not solve our problem. We have to depend on a national program to reduce SO 2 emissions over which we have no control.

I would like to turn for a moment to the situation in New Hampshire. There is no doubt that our precipitation is acidic and that we are experiencing excessive sulfate loadings in the precipitation which falls on our state. The New Hampshire Water Supply and Pollution Control Commission calculated the true average pH for a ten-year period to be 3.94 and in 1981 the sulfate loading of the deposition from some 18 storms was over twice the amount determined to cause damage.

We have well documented evidence that acid deposition is damaging our aquatic ecosystems. Lakes and ponds which previously were healthy and supported diverse aquatic life in many instances are either void of life or are fast losing their protection from acid precipitation.

Our forests which cover over 80% of the state, providing raw materials to our forest industry, an important land base for recreation and tourism and a valuable investment to many private landowners are not immune from the effects of acid precipitation. While we have little documented evidence on damage to New Hampshire's forests from acid deposition, our review of research from Canada, Vermont and Europe gives us reason to be gravely concerned over the health of our forests -- and for good reason:

We have recently heard reports that several white pine stands in the southern portion of the state show significant progressive decline in growth over the last 20 years. While additional research is needed to determine whether these occurrences indicate a trend and to identify the cause of such a decline, we cannot ignore the fact that this may well represent the fate of our forests -- and if so, we must look at the implications.

The most obvious one would be the economic loss and job disruption associated with New Hampshire's forest industries. Losses to the forest products industry associated with decreased growth are significant. An estimated 1% growth reduction represents a $35 million loss annually in regional lumber and paper industry values and a $45 million loss in related industries. A 5% growth reduction represents an estimated $200-400 million loss to the region.

More difficult to assess and yet no less important are the implications for the investments of private landowners who depend on the health of their forest land, the implication for our recreation and tourist industry which depends in large part on New Hampshire's forests and the implication for our water quality supplies.

We urge that any national program to reduce acid deposition focus specifically on providing meaningful reductions in SO 2 emissions. It is well documented that in order to provide minimal protection we need to reduce SO 2 emissions by 50%. A program which provides for less may, in fact, prove meaningless and ineffective in preventing further damage. Few need reminding that the effects of acid precipitation are irreversible. We must provide for at least the minimum to protect human health, our forests and water supplies. We will be asked to help pay for the program on top of what we are paying in damages. Many of us are more than willing to do so, but we need o know that we will be protected from further damage.

Finally, I would urge, in addition to an immediate national control program, that a prompt, coordinated and well-funded effort get under way to look at the effect of acid precipitation on northern New England's forests. Such an effort should address, among other things, the extend of growth decline in white pine and the extent to which similar trends are developing for other species such as white oak and ash.

We cannot afford to wait until the forests and human health evidence the same degree of damage with the same degree of certainty that has occurred on our lakes and ponds. A national program must be implemented immediately to reduce SO 2 emissions so we can stop damage which is presently occuring but so that we can also avert future damage. It makes good economic policy and good resource policy to practice preventive medicine.

Thank you for the opportunity to comment.

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AMERICAN LUNG ASSOCIATION
The Christmas Seal People ®

SULFUR OXIDES AND PUBLIC HEALTH: EVIDENCE OF GREATER RISKS

Prepared by:

KAWECKI ASSOCIATES
Chevy Chase, Maryland

August 1983

[Note: The following has been excerpted from the above named report. The complete document has been retained in committee files.]

National Headquarters: 1740 Broadway, New York, N.Y. 10019 • James A. Swomley, Managing Director

PREFACE

During the past two decades, researchers have found harmful health effects occurring at lower and lower levels of air pollution. This trend is attributed to our growing ability to measure and understand air pollution and its effects. Historically, the standards for safe amounts of sulfur oxides and particulate matter in the air were based primarily on the results of epidemiological studies. While controlled studies on humans showed some of the same kinds of health effects observed epidemiologically, the exposure levels required to avoke these responses were much higher -- subjects showed virtually no measurable response to sulfur dioxide at levels lower than 1 ppm or to sulfuric acid concentrations below 1000 $\mu g/m^3$. Today's research findings contrast sharply with these earlier controlled studies. Scientific journals report effects on pulmonary function from short-term exposure to sulfur dioxide at 0.25 ppm and to sulfuric acid at 100 $\mu g/m^3$, leaving little, if any, margin of safety for protecting sensitive individuals. Because these levels approach those that may occur in the ambient air, prudence dictates reexamination of the control strategies for sulfur emissions from the burning of fossil fuels.

EXECUTIVE SUMMARY

The emissions of sulfur-bearing compounds from burning coal and oil need to be controlled more effectively. Despite Government efforts, nearly 30 million tons of sulfur oxides are emitted from these sources into the air each year in the United States. These pollutants remain airborne for long periods of time and may travel great distances, creating high concentrations far from emission sources. Atmospheric levels of sulfur dioxide, sulfuric acid, and sulfates are high enough in some areas to be harmful to the public.

Sulfur dioxide is the main sulfur product of combustion. As the sulfur content in the fuel increases, so does the level of sulfur oxides. In the air, sulfur dioxide reacts over time to form sulfuric acid and other sulfate salts. Sulfur dioxide itself is toxic. In laboratory tests, exposure to the gas for less than one hour at concentrations of 0.25 to 0.5 ppm was found to constrict the respiratory airways of asthmatics and also to cause wheezing and shortness of breath. Normal subjects have also shown respiratory symptoms when exposed to sulfur dioxide, but at higher concentrations. Sulfuric acid is an extremely reactive substance which, like sulfur dioxide, has been found to impede the respiratory system's ability to clear itself of foreign matter and to impair breathing functions in laboratory subjects. Brief exposure to sulfate particles at concentrations as low as 100 $\mu g/m^3$ has likewise shown effects on airway resistance and respiratory volume. In the ambient air, actual exposure may be much longer, since elevated sulfate levels can persist for 12 hours a day. Combinations of sulfur oxides, ozone, and other major pollutants may be more hazardous than each of these substances alone--laboratory tests have not resolved the question. However, a number of epidemiological studies show clear evidence of increased sickness and mortality in the population at large caused by elevated concentrations of sulfur dioxide and particulate matter in the ambient air. On a national scale, at high pollution levels, fractional increases in sulfur dioxide and sulfate concentrations may well take an increasing toll in illness and death, particularly among the elderly, persons with respiratory and cardiovascular disease, and other susceptible individuals.

CONCLUSIONS

The efforts by federal, state and local authorities to reduce pollution of the air by sulfur oxides have achieved mixed results. While concentrations of sulfur oxides near emission sources have lessened considerably, concentrations of SO_2 and its transformation products, sulfuric acid and other sulfate species, many miles away from these sources have, at best, remained the same and, in certain areas of the United States have even increased. So much attention on the long-range transport of sulfur pollution has been given to ecological effects--acid rain--that many have overlooked the effects on public health that this long-range transport poses.

The observed effects on asthmatics of SO_2 at 0.25 to 0.5 ppm and of H_2SO_4 at 100 $\mu g/m^3$ should be taken into account in making decisions regarding control strategies for SO_2. Temporary small changes in pulmonary function in healthy adults exposed to SO_2 levels of 1.0 ppm or H_2SO_4 levels of 1,000 $\mu g/m^3$ are of less concern than effects observed in asthmatics at much lower concentrations. These effects are likely to occur at SO_2 and sulfate levels in the ambient air. Their seriousness is reflected by the fact that airway obstruction and symptoms such as wheezing and dyspnea are among factors considered by physicians in determining the need to hospitalize asthma patients.

Relatively high concentrations of SO_2 and sulfuric acid have been reported in the Los Angeles basin area and in the northeastern United States. During the summer season in the Northeast, levels of sulfuric acid/sulfates range from 15 to 20 $\mu g/m^3$, while peaks of 25 $\mu g/m^3$ and higher are not uncommon. During this time, ozone levels are also elevated. Moreover, the potentiation of SO_2-induced bronchoconstriction by cold, dry air raises equal concern during the winter season, when SO_2 levels reach their highest, for example, in the Northeast.

Both the elevated sulfate and SO_2 concentrations combined with elevated ozone levels increase the health risks to those people with preexisting illnesses, those spending time out of doors, and those engaged in outside physical activity. This group includes asthmatics, people with allergies, those with chronic obstructive lung disease and cardiovascular disease, those involved in outdoor occupations, children, and the elderly. During the summer season, as noted previously, both children and the elderly are particularly sensitive to exposure to sulfate air pollution. During the winter season, these same groups are particularly sensitive to exposure to SO_2. While it is difficult to estimate the number of people affected by SO_2 and sulfuric acid aerosols, a variety of respiratory-related illnesses are likely to occur in sensitive populations during peak concentrations.

Health Effects of Air Pollution

AMERICAN THORACIC SOCIETY
Medical Section of
AMERICAN LUNG ASSOCIATION
1978

[Note: The following has been excerpted from the above named report. The complete document has been retained in committee files.]

Summary

Evidence for an association of air pollution with adverse effects on human health is drawn from 3 sources: animal experiments, experimental human exposures, and epidemiologic studies of exposed human populations. Each source of evidence has particular strengths and weaknesses.

Animal experiments provide information on a broad range of toxicologic effects and give insights into biologic mechanisms of response, but results cannot be directly extrapolated to human exposures. Through experimental human studies, human responses to individual pollutants can be precisely quantified, but even these findings may not be applicable to the population of "sensitive" persons or to the general population exposed to a complex and changing pollutant mix. Epidemiologic investigators can study effects of real-life exposures in various population subgroups; however, it is difficult to attribute the observed adverse health effects to specific concentrations of any 1 pollutant. Quantitative dose-response relationships are emerging from all 3 disciplines, and in some cases there is increasing convergence of evidence that provides a strong basis for regulation and public health protection. In any case, regulatory bodies must depend on the judgment of clinicians and other health scientists for an interpretation of the various and sometimes contradictory lines of evidence on the health effects of air pollution.

Adverse health effects have been associated with 3 major types of air pollution related to 3 major source categories: (*1*) the sulfur oxide and particulate complex arising from the combustion of sulfur-containing fossil fuels, particularly in fossil-fueled power plants, (*2*) photochemical oxidants formed in the atmosphere from a complex chemical reaction between precursor hydrocarbon compounds and nitrogen oxides, and carbon monoxide, both of which are largely related to motor vehicle emissions, and (*3*) a miscellaneous class of air pollutants such as arsenic, asbestos, beryllium, cadmium, hydrogen sulfide, lead, and mercury, which are mostly emitted by localized point sources, such as smelters, refineries, and manufacturing plants.

Nine general categories of adverse health effects have been related to human exposure to different air pollutants. These categories are listed in table 1.

Air pollution-associated mortality. Historically, the clearest evidence for an association between sulfur oxide/particulate air pollution and death was manifested by a number of acute air pollution episodes during which unfavorable meteorologic conditions resulted in several days of air stagnation and greatly increased concentrations of atmospheric pollutants. A striking increase in daily mortality occurred during these episodes, primarily among persons already afflicted with cardiac and respiratory disease, although even some healthy persons were affected. Fortunately, episodes of the duration and intensity reported before the early 1960s no longer seem to occur, at least in the cities of the United States and Western Europe. Given the many sources of atmospheric emissions in most urban areas and the generalized effect of air stagnations on all emission sources, no single air pollutant could be established as the causal factor for the observed excess of mortality.

Photochemical oxidants (ozone and nitrogen dioxide) are extremely toxic and even at relatively low ambient concentrations are respiratory-tract irritants. These properties have led some persons to express concern that photochemical oxidants might produce an air pollution episode with marked excess of mortality. None has been recorded thus far, possibly because of the dependence of this type of pollution on diurnal peaks of solar energy and the absence of sustained high concentrations of these pollutants.

The association of daily variations in sulfur oxide/particulate air pollution of lesser magnitude has also been studied with respect to fluctuations in daily mortality in metropolitan areas. Analyses of several sets of data tend to agree in finding greater mortality (from all causes combined) on days of greater pollution, without a clear-cut threshold for this response. However, the association between air pollution and daily mortality is not described by a simple linear relationship, and other determinants of day-to-day changes in mortality make it difficult to specify a pollutant concentration at which excess deaths begin to occur. Recent studies find little evidence for a relationship between air pollution and day-to-day mortality.

Studies of oxidant air pollution and daily mortality have not demonstrated a relationship between deaths and direct measurements of peak or daily oxidant concentrations among residents of Los Angeles County, where some of the highest ambient oxidant concentrations are reported. In laboratory animals, mortality from exposure to ozone is sharply dependent on concentration. Genetic factors and previous dietary intake, especially of vitamin E, also alter the sensitivity of different strains.

Investigators in various countries have reported associations between residence in areas of heavy air pollution and mortality from all causes combined, and from bronchitis and other respiratory causes. Most of these studies have shown this relationship with the sulfur oxide/particulate complex.

Chronic respiratory disease morbidity. Studies of chronic respiratory disease and air pollution conducted throughout the world have indicated that a relationship may exist between the prevalence of chronic respiratory symptoms and the sulfur oxide/particulate complex. Experimentally, ozone and nitrogen dioxide can induce emphysema-like changes in ex-

TABLE 1

ADVERSE HEALTH EFFECTS OF AIR POLLUTION*

Categories of Effects	*Location in Tables*
Air pollution-associated mortality	2-4
Chronic respiratory disease morbidity	5
Exacerbation of asthma	6
Acute respiratory disease morbidity	7-8
Effects on ventilatory function	9
Cancer of the lung	
Heart disease	
Sensory, neurological, and behavioral effects	
Effects from persistent metals and other pollutant residues	
Categories of Health-Related Air Pollutants	
The sulfur oxide/particulate complex	12
Photochemical oxidants	13
Nitrogen dioxide	14
Carbon monoxide	15
Other air pollutants	

*References are cited in text and tables.

posed animals. Although these pollutants are not part of the sulfur oxide/particulate complex, their presence in many urban areas may be one of the factors accounting for these observed relationships. Few of the studies of chronic bronchitis and air pollution have been able to obtain measurements of air pollution in close proximity to the place of residence. Chronic respiratory disease appears to develop in response to cumulative and interacting factors, whether these be pack-years of cigarettes, recurrent infections beginning in childhood, or long-term exposure to occupational dusts and air pollution. The weight of evidence suggests that, although cigarette smoking exerts a much stronger effect, air pollution can be additive, and possibly more than additive, with cigarette smoking as a risk factor in the development of chronic respiratory disease.

Studies of the daily symptom status of patients with chronic obstructive lung disease show relationships between disease status and air pollution concentrations at relatively high concentrations of sulfur dioxide and particulates. Low temperatures can exert a greater effect than air pollution, and the similar temporal pattern of air pollution and cold temperatures in the past may have accounted for some of the relationships observed between air pollution and disease aggravation. British studies suggest that improvements in air quality during the past 10 to 15 years in England have largely abated the relationships between air pollution and disease aggravation.

Exacerbation of asthma. Asthmatic patients represent another segment of the population that appears to be susceptible to short-term peak concentration of air pollutants. Increased rates of asthma attacks were noted during episodes of sulfur oxide/particulate and photochemical oxidant air pollution. Several studies based on daily diaries kept by panels of asthmatic patients have shown a gradient of response between asthma attacks and days of higher concentrations of air pollution. Often, daily temperature variations were more strongly correlated with attack rates, but even when temperature-adjusted rates were computed, air pollution still exerted a significant effect. A recent experimental study in which asthmatic patients were exposed to relatively low concentrations of nitrogen dioxide before challenge with a chemical bronchoconstricting agent suggests the possibility that air pollution may enhance the asthmatic patient's reactivity to other stimuli.

The asthmatic person appears to represent an extreme on the scale of respiratory sensitivity to external stimuli, and the sum of the studies analyzed indicates that increased air pollution concentrations are 1 of many factors that can precipitate attacks in some fraction of asthmatic patients. Experimental evidence suggests a continuum in the dose-response relationship, with increasing numbers of asthmatic patients responding at higher concentrations.

Acute respiratory disease morbidity. Air pollution and impaired resistance to respiratory infection have been shown in laboratory animals at ambient or near ambient concentrations of ozone and nitrogen dioxide. In a number of studies of human adults, investigators have also observed a greater incidence of acute respiratory illness in communities with increased sulfur oxide/particulate concentrations. The sum of these studies supports a probable association between increased acute lower respiratory tract disease (acute bronchitis, pneumonia, other acute chest illnesses) in adults, and air pollution with the sulfur oxide/particulate complex and possibly with nitrogen oxides. The pollutant concentrations at which increased risk of acute illness occurs have not been established.

Rates of acute respiratory illness in children, particularly of illnesses of the lower respiratory tract, have been repeatedly associated with residence in more polluted communities affected by the sulfur oxide/particulate complex. These excess rates of illness can not be accounted for by social class, family size, or area differences in residential mobility. In several reports, the frequency and severity of acute lower respiratory disease have been shown to increase with the geographic gradient in air pollution and to diminish when air quality is improved in the more polluted areas.

Longitudinal studies of children conducted in England show an association between the prevalence of cough in young adults and exposure to air pollution in childhood. Cigarette smoking in adulthood and a history of childhood illness exerted a stronger influence on the prevalence of cough in young adulthood; nevertheless, the contribution of air pollution was detectable.

Effects on ventilatory function. Geographic differences in various air pollution indices have frequently been related to differences in ventilatory function, particularly in school children. A number of such observations have been reported in studies from England, Japan, the United States, Canada, and the Netherlands. Children residing in more polluted communities affected by the sulfur oxide/particulate complex tend to show diminished ventilatory function when compared with their counterparts—adjusted for age, sex, race, height, and social class—living in less polluted areas. Similar differences have not been consistently associated with photochemical oxidant concentrations in California, although an association of ambient oxidant concentrations and ventilatory function has been noted in England and Japan when air pollution concentrations decreased in the affected regions. Filtered air chamber studies in California also suggest improved ventilatory function status in adults with chronic obstructive airway disease when these patients breathed filtered air from which pollutants had been removed.

Experimental human exposures have been particularly useful in determining the precise concentrations at which a single air pollutant, or combinations of several pollutants, can affect the airways of healthy adults. In some cases, adults with asthma or other forms of obstructive airway disease have been studied in this manner. A wide variability in human airway response to sulfur dioxide has been demonstrated in various experimental studies, with some evidence that sulfur dioxide can enhance the bronchoconstrictive effect of ozone on lung function.

Experimental exposure of human subjects to ozone alone reveals effects on ventilatory function at concentrations that are reached in ambient air, especially in areas characterized by oxidant pollution. These effects are reversible and, in themselves, do not necessarily constitute risk of disease, although the associated symptoms can impair performance of normal activities during and immediately after exposure. Exercise during exposure increases the pollutant effect on ventilatory function. Recent studies have reported a pollutant-induced enhancement of the effect of pharmacologic bronchoconstricting agents at relatively low concentrations of nitrogen dioxide, ozone, and sulfur dioxide. The significance of these findings with respect to combined exposure of hypersensitive persons to pollutants and naturally occurring bronchoconstricting agents remains to be evaluated.

Cancer of the lung. Several carcinogens have been detected in air. Of particular concern are recent reports of nitrosamines and polycyclic hydrocarbons. Based on the evidence gathered thus far, the suspicion that air pollution leads to lung cancer remains neither proved nor disproved. The overwhelming influence of cigarette smoking, the contribution of occupational exposures, the scarcity of good measurements of potential atmospheric carcinogens, and the long lag between first exposure and manifestation of cancer all contribute to the difficulty of obtaining evidence for a postulated relationship between air pollution and lung cancer.

Cardiovascular disease. Epidemiologic studies and experimental human exposures concur in demonstrating an adverse effect of ambient concentrations of carbon monoxide on persons with some forms of pre-existing coronary heart disease and peripheral atherosclerosis. Higher rates of case fatality among patients admitted to hospitals for myocardial infarction have been observed during periods of relatively increased carbon monoxide pollution. In experimental studies of patients with angina pectoris, carbon monoxide significantly decreased the amount of exertion that could be undertaken before onset of chest pain. Similar effects with respect to leg pain have been reported in men with peripheral artery disease. A further possible contribution to coronary heart disease is suggested by studies of animals in which carbon monoxide enhanced the effect of increased serum cholesterol on the development of atherosclerosis in rabbits that were fed cholesterol.

Sensory, neurologic, and behavioral effects. The odor of some airborne substances and the irritation to the eyes, nose, and throat caused by other pollutants are the most common and annoying aspects of air pollution for many persons. Perception of these effects is very real, but it is difficult to quantify their perception in populations. Odor annoyance survey methods have been developed and can be used for monitoring odorous pollutants. Ozone, the major component of photochemical smog, is directly irritating to the pharynx and trachea, causing a burning sensation in the upper part of the chest, particularly during vigorous exercise. These effects have been reported in Los Angeles and parts of Japan on "smoggy" days. The long-term health implications of this category of effects are largely unknown.

Carbon monoxide can alter human neurobehavorial performance as well as cardiac function. Decrements in vigilance tasks have been observed at relatively low carboxyhemoglobin saturations.

Inhalation of significant amounts of airborne lead can also give rise to neurologic changes, although concentrations of airborne lead commonly encountered in communities have not been shown to produce these changes.

Effects from persistent metals and other pollutant residues. In certain areas, exposure to lead has been shown to increase body stores, produce related biochemical impairments, and cause slower nerve conduction. Such effects may impair neural development in children, but data on this type of effect are scant, and no agreement exists. Local sources of other persisting materials, such as smelters, refineries, and chemical plants, can also affect storage of persistent materials and produce biochemical effects.

Health effects of the sulfur oxide/particulate complex. The sulfur oxide/particulate complex is not a chemically or physically specific mixture, but one that varies from place to place in particle-size distribution, oxidation state, and chemical species. Greatly increased ambient concentrations have been consistently associated with greater mortality during episodes of air pollution and with the aggravation of symptoms in subjects with heart and lung disease. In more polluted cities, there is considerable evidence for a greater prevalence of chronic respiratory disease in adults and an increased incidence of acute respiratory disease and depressed lung function in children.

Animal experiments and particle-size characteristics suggest that sulfates and other transformation products of sulfur dioxide may be more responsible for the biologic reactivity of the sulfur oxide/particulate complex than are direct measurements of sulfur dioxide and total particulate matter. Interactions between sulfates, metallic cations, and ammonia have been found; these interactions make particularly important the chemical identification of sulfur oxide/particulate fractions. For practical reasons, ambient concentrations of sulfur dioxide and total suspended particulates, or smoke, are commonly reported and used to assess the quality of air for this class of pollutants. Concentrations of sulfur dioxide and particulates each in excess of 100 µg per m^3 are generally associated with the augmentation of respiratory symptoms, lung function changes, and increased risk of acute and chronic respiratory disease.

Health effects of photochemical oxidants. The primary target tissues of inhaled ozone, which constitutes the largest component of the photochemical oxidant complex, are the respiratory tract and pulmonary parenchyma. Experimental exposure of animals to ozone in the range of 200 to 1,000 µg per m^3 (0.10 to 0.50 parts per million [ppm]) induces structural changes in lung tissue and increased susceptibility to respiratory pathogens. In rats and mice, mortality occurs with continuous exposure to ozone of 2,000 µg per m^3 (1 ppm) or more. Morphologic changes induced at lower concentrations are not fully reversible. Experimental human exposure to ozone for 2 hours causes decrements in various measures of pulmonary function in healthy exercising men at concentrations of 740 µg per m^3 (0.37 ppm) or more, and there is good reason to believe that these changes take place at lower concentrations in more reactive subjects. Epidemiologic studies in the Los Angeles basin and in Japan have reported associations between ambient ozone or oxidant concentrations in the range of 200 to 600 µg per m^3 (0.10 to 0.30 ppm) in the presence of other pollutants and eye irritation, cough, and chest discomfort, especially in exercising groups.

Health effects of nitrogen dioxide. Experimental short-term exposure of healthy adults or of persons with chronic bronchitis appears to have no detectable effect on ventilatory function until concentrations of 3,000 to 3,760 µg per m^3 (1.6 to 2.0 ppm) are reached. Recently, one investigator reported an enhancement of the bronchoconstrictor effect of pharmacologic agents in asthmatic patients pre-exposed to 210 µg of nitrogen dioxide per m^3 (0.11 ppm) but the relevance of these findings to naturally occurring combinations of bronchoconstrictors and ambient nitrogen dioxide is unknown.

Like ozone, nitrogen dioxide induces various structural changes in the lungs of laboratory animals. Increased susceptibility to respiratory pathogens has also been produced by continuous or intermittent exposure to nitrogen dioxide for 3 to 6 months at concentrations of 940 to 1,880 μg per m^3 (0.5 to 1.0 ppm).

Epidemiologic studies of population groups exposed to nitrogen dioxide in the presence of other pollutants have shown associations between increased incidence of acute respiratory disease and ambient concentrations of nitrogen dioxide in the range of 150 to 280 μg per m^3 (0.08 to 0.15 ppm). Coexisting sulfur oxide/particulate pollutants complicate the application of these findings to the general environment. At high concentrations, observed with occupational exposures, maximal effects of nitrogen dioxide may occur from 1 to 3 days after exposure. Some epidemiologic data indicate that acute reactions to complex urban pollutants may occur 1 or 2 days after peak exposures.

Health effects of carbon monoxide. The effects of carbon monoxide stem primarily from its affinity with oxygen-carrying hemoproteins, which causes a leftward shift and steeper slope of the oxyhemoglobin dissociation curve and decreases the amount of such hemoprotein available for oxygen transport. Persons with circulatory diseases who are unable to compensate for oxygen deprivation by increased blood flow to affected organs are particularly likely to experience adverse effects from exposure to relatively low concentrations of carbon monoxide. Several experimental studies have shown that persons with coronary heart disease, as manifested by angina pectoris, experience chest pain significantly earlier during exertion when carboxyhemoglobin concentrations increase from baseline (usually 0.5 per cent) to 2.5-3.0 per cent, an effect that can be induced by 1-hour exposures to carbon monoxide at concentrations of 80 to 100 mg per m^3 or by 8-hour exposures to concentrations of 17 to 21 mg per m^3. Suspected long-term effects of carbon monoxide on arteriosclerosis and vascular disease have been suggested by experimental exposure of animals and by epidemiologic studies of smokers.

Carbon monoxide has also been shown to have an effect on the function of the central nervous system. In humans, experimental studies have reported impairment of vigilance tasks in the range of carboxyhemoglobin concentrations from 3.0 to 6.5 per cent. Epidemiologic studies have suggested an effect of ambient carbon monoxide exposure on daily mortality variations and case-fatality rates for persons hospitalized with acute myocardial infarction.

Health effects of other pollutants. Lead in ambient air has been associated with increased lead concentrations in the blood of adults and children. A contribution of motor vehicle emissions to lead in dirt and street dust may account in part for a general finding that urban children, especially those living close to dense traffic, have higher blood lead concentrations than do rural children.

Asbestos, mercury, beryllium, and vinyl chloride are designated as hazardous air pollutants because they may be associated with disease risk at relatively low concentrations. These materials may accumulate in the body over time and induce adverse effects of insidious onset.

Conclusion. Animal experiments and occupational and experimental human findings, together with the experience of human populations exposed to community pollution, have provided qualitative and quantitative understanding of health effects of community air pollution. Air quality standards have been developed and supported in order to prevent such effects. The adequacy of scientific data and their interpretations have been reviewed by the National Academy of Sciences and by other organizations.

In general, the standards have been set at concentrations that were judged to protect sensitive groups from significant health impairment. Although it would be desirable to establish a standard at some concentration below a demonstrable threshold for adverse effects, in practice it is not feasible to determine these thresholds among various segments of the population. In some cases, as in the effect of exposure to carbon monoxide on the oxygen-carrying capacity of the blood, there is no practical threshold. Standards also do not guarantee or assure that unusually sensitive persons will be protected against all adverse health effects, especially if the effects are enhanced in the presence of other pollutants, other health conditions exist simultaneously, or extraordinary meteorologic conditions occur. At exposures to pollutant concentrations above the standards, there is increasing probability of damage to human health.

4. Evaluating the Over-all Health Risks of Air Pollution

Are present air quality standards adequate, too stringent, or too lenient for protection of public health? What will be the likely health effects of burning more coal or of postponing achievement of strict automobile emission standards? Do the health benefits of sulfur oxide control justify the high cost of control technologies? These questions are often and reasonably asked by government, industry, and the public. in a sense, they can be reduced to one simple query: what is the over-all health risk of air pollution? The answer is by no means simple, but physicians and lung associations are expected to arrive at well informed opinions for their communities.

Issues in the Evaluation of Air Pollution/Health Risks

Evaluation of health risks involves 4 component tasks (Lowrance, 1976): (*1*) identifying the health effects of air pollution, (*2*) quantifying these effects at various concentrations, (*3*) estimating how many people are exposed at these concentrations, and (*4*) calculating the over-all health risk associated with a given degree of air quality.

With the abundance of evidence described in Sections 2 and 3, identification of the health effects of air pollution would seem to be reasonably straightforward. Yet there is considerable disagreement even within the scientific community about the health effects of specific pollutants, e.g., whether SO_2, NO_2, or other oxides of sulfur and nitrogen at commonly occurring concentrations are agents of disease in our environment. It is far easier to demonstrate the health effects of air pollution than to determine the health effects of specific amounts of sulfur oxides emitted by fossil fuel power plants, or of photochemical oxidants formed from nitrogen oxides and hydrocarbons emitted by motor vehicles. Moreover, we are concerned not only with acute and readily detectable effects of air pollution, but with cumulative exposures and chronic and often delayed effects. Biologic response to air pollution can range from irritating sensory effects and physiologic changes to disease, disability, and death. We have limited ability to relate these varieties of effects to combinations of air pollutants, and to isolate the effects of air pollution from other causal and contributing factors.

Quantifying air pollution-related health effects at various concentrations entails the formulation of dose-response curves. In figures 4a to 4c, the family of curves that could be drawn for different health effects as modified by factors of age (and other socio-demographic characteristics) and environmental variables other than air pollution is illustrated. That a given increment of air pollution exposure will increase the frequency of some health effects, whereas other effects over the same range of exposures may show no corresponding change, is suggested by figure 4a. In figure 4b is shown the greater susceptibility of older populations at the same concentrations as in figure 4a, whereas in figure 4c the modifying effect of season or temperature on the dose-response-relationship is displayed. Each of these illustrations could be partially documented from the body of air pollution/health effects literature. However, there is no single air pollutant and no air pollution-related health effect about which we possess sufficient data to draw a reasonably complete family of curves. There are, therefore, large gaps in our knowledge for answering the question: how many people will experience specific adverse effects as a result of a projected change in exposure to air pollution?

Even if we identified the range of health effects and the family of dose-response relationships associated with air pollution, we would be hard pressed to obtain a satisfactory set of air pollution measurements of population exposure. Air monitoring networks have not been designed to provide estimates of population doses. Often, a single monitoring station exists in a metropolitan area or in a community of several hundred thousand people, and this monitor is used to estimate the exposure of that population and to differentiate one community from another. Even in these cases, the most sophisticated monitoring stations usually provide data on relatively few air pollutants—those that can be readily monitored with field-test instruments. (For some pollutants, such as CO or lead, breath samples or blood samples may serve as a more accurate integrator of human exposure than elaborate, stationary networks.) Thus, there are many deficiencies of data in studies that attempt to estimate the total population dose.

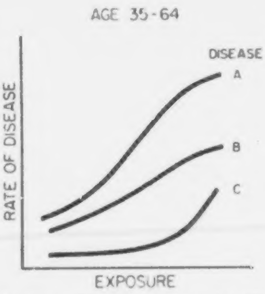
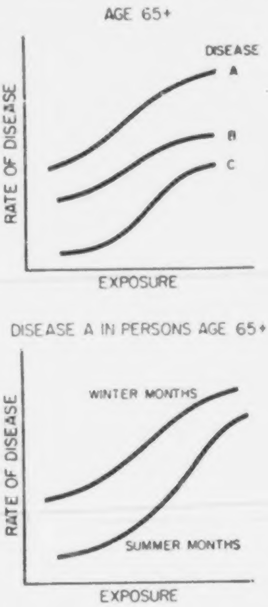


Fig 4a-c. Hypothetical health damage functions by disease, age, and season

To accomplish the final step in risk evaluation, we face the task of calculating the over-all risk to the population of a given degree of air quality. In effect, we would like to apply each set of damage functions for a pollutant to the air pollution dose estimates for all segments of the population. We must engage in this effort despite the many deficiencies in the data concerning the nature of the health effect, the form and position of the family of dose response curves, and the extent of population exposure. Given our present knowledge, estimates of over-all risk are necessarily judgmental in the sense that, to fill in the many data gaps, assumptions must be made that cannot be proved or disproved scientifically. In making these assumptions, scientists are generally aware that they are making judgments that go beyond the narrow limits of scientifically proved facts and that their risk estimates may be modified as more data are acquired. The estimates are, however, useful for suggesting whether an anticipated change in air quality may have an associated health effect and what relative magnitude of effects (or benefits) might be expected from a change in population exposure. Estimates of absolute changes in risk are necessarily much more specula-



tive. Similar processes of estimation in the face of uncertainty occur in many other areas of public policy, such as energy conservation, control of drug use, and pesticide registration.

Because much of our knowledge of air pollution/health effects relationships is based on studies of exposed communities, we may feel more confident in expecting more adverse health effects with increasing population exposure than in defending the judgment that lower exposures will result in a certain quantitative health benefit. Even the expectation of more effects at higher exposure must be qualified by possible temporal changes in modifying factors and in the composition of the pollutants at the higher concentrations.

Examples of Estimates of Air Pollution/Health Risks

One of the most often cited reports attempting to quantify the total health risk of air pollution is the paper of Lave and Seskin (1970). These authors estimated the impact of air pollution on various disease states by extrapolating from various reported studies and by analyzing the urban factor in lung cancer and chronic respiratory disease. To account for the effect of other contributing factors, they performed a multiple regression analysis in which geographical differences in mortality were expressed as a function of population density, race, sex, age, socioeconomic level, and air pollution (as measured twice monthly at 1 or more monitoring stations in each of 114 metropolitan areas). From this analysis, the authors concluded that a 50 per cent decrease in urban air pollution would be expected to decrease by 25 to 50 per cent the urban excess in mortality and morbidity from bronchitis, 25 per cent of the urban excess in lung cancer and other respiratory diseases, 15 per cent of the urban excess in cancer in general, and 10 per cent of the urban excess in cardiovascular disease mortality. The economic and health consequences of these estimated benefits were further assessed. A decrease in urban air pollution by 50 per cent was projected to decrease health costs by $2 billion and to lead to a 4.5 per cent decrease in the economic costs associated with all morbidity and mortality. In re-analyzing Lave and Seskin's estimates to take account of indirect costs, Barrett and Waddell (1973) computed at $4.3 billion decrease in health costs associated with a 50 per cent decrease in urban air pollution. Waddell (1973) also estimated health benefits of $3.73 billion based on Lave and Seskin's analysis, if air pollution concentrations in all U.S. cities decreased to the concentrations required by the 1970 national air quality standards.

Williams and Justus (1974) also used Lave and Seskin's analysis, but arrived at a smaller estimate of $62 to $311 million for the annual health cost of air pollution. These authors objected that Lave and Seskin's estimates were double-counted, because of the major portion of urban air pollution was represented by SO_2 and particulate pollution data in the multiple regression model, and other economists added health costs attributable to other pollutants, as well. Williams and Justus also assert that cigarette smoking and air pollution are synergistic, whereas the evidence for additive versus synergistic effects is by no means established.

Because each of the above estimates of the over-all health impact of air pollution is based on the analysis of Lave and Seskin (1970), it is desirable to evaluate the quality of the underlying data and the method used by the latter authors to reach their conclusions. As noted in Section 2, many intervening factors can distort the apparent association between air pollution and disease when geographic studies are undertaken. Particularly important as potential confounders are cigarette smoking, social class, and occupational exposures. More polluted areas are undesirable places to live, hence, higher-income groups with less direct exposure to occupational dusts tend to reside in less polluted neighborhoods. Further, there is ample evidence that professional and managerial groups experience a lower over-all mortality than do other working populations (Ott *et al.*, 1976). Surveys of smoking habits in different occupational categories (Higgins *et al.*, 1977 [185]) also reveal a generally higher prevalence of cigarette smoking among blue-collar than among white-collar workers. Because Lave and Seskin derived their data from census information, they were unable to evaluate possible differences in the distribution of smoking habits and occupational categories in the 114 metropolitan areas of their study. It is not at all unlikely that smoking and occupational differences may have accounted for a significant portion of the mortality and morbidity effects attributed to air pollution.

Lave and Seskin's method of analysis also has serious limitations. By using a geographic or "ecologic" approach to the association between air pollution and disease, they were unable to determine whether the persons who died of lung cancer and other respiratory diseases were actually exposed to the air pollution that was attributed to their metropolitan areas. U.S. populations are very mobile, and a significant fraction of the population in most metropolitan areas is likely to have moved into that area within the past decade. Some persons migrate from low- to high-pollution areas, and others in the opposite direction. Thus, a stationary air monitoring station is not only unrepresentative of the air pollution in an entire metropolitan area, but is also a poor reflection of the cumulative exposure of a highly mobile population. Hence, geographical studies similar to that of Lave and Seskin are unlikely to provide reasonable estimates of differences in population exposure to air pollution. From these considerations, it would appear to be far beyond the quality of the data or the method of analysis to be able to attribute 25 to 50 per cent of the urban excess in lung cancer and other respiratory diseases to a given change in air quality. Too many strong determinants of these diseases were left unmeasured and therefore unanalyzed, and these determinants are very likely to be confounders of the apparent geographic association between air pollution and disease.

The appeal of the approach of Lave and Seskin is that it provides the administrator quantitative estimates of the magnitude of the health benefit to be expected from controlling air pollution at a certain concentration. That these estimates are not based on measures of individual exposure linked to individual causes of death is usually overlooked. It is important to point out that in epidemiologic analyses, geographic associations between aggregate units of observation (such as an entire metropolitan population) are usually limited to generating hypotheses about exposure/disease relationships. To evaluate individual risk of disease from exposure to environmental hazards, epidemiologists rely on morbidity or mortality records that can be linked directly to some estimate of the exposure of the person from whom the record was obtained. At present, evidence from such individual studies has not been accumulated in a standardized or comparable method to allow us to make quantitative estimates that apply to multi-state populations in the United States.

In a chapter written for a report from the National Academy of Sciences, Goldstein (1975) attempted to draw risk estimates that consider constitutional factors, occupational exposure, contribution of cigarette smoking, and the fraction of the population exposed to air pollution. The author recognized that these estimates cannot be based on statistical extrapolations from "hard data," but are instead derived from judgments that necessarily go beyond the limitations of the existing data base. With considerable reservations, he judged that, whereas 70 per cent of chronic respiratory disease is attributable to cigarette smoking, 10 per cent of the prevalence of this disease may be associated with sulfur oxide/particulate exposure. He also suggested that 10 per cent of acute morbidity in patients with chronic obstructive lung disease, 1 per cent of acute respiratory illness, 10 per cent of asthma episodes in polluted communities (5 per cent nationwide) and 2 per cent of total mortality are reasonably associated with air pollution.

Several other air pollution/health risk estimates have been made (North and Merkhofer, 1975, Panel on Air Quality, Noise and Health, 1976; Stolwijk and coworkers, 1975; National Environmental Research Center, 1974). This topic was recently reviewed by Herman (1977) for the American Lung Association.

Although these estimates vary, in one sense, they all agree in projecting more adverse health effects of air pollution concentrations greater than those at present, but the relative or absolute magnitude of these increases varies considerably from report to report. In one report (North and Merkhofer, 1975), the effect of variations in underlying assumptions was subjected to a sensitivity analysis, and the magnitude of the resulting health risk was shown to change considerably for some health effects, but not for others.

The issues involved in evaluation of air pollution/health risks, as previously discussed, will not be satisfactorily resolved in the near future. Progress in our understanding of the effects of air pollution on the full range of biologic responses possible in humans, and in measuring population exposure, is time consuming.

The tasks are complex and exceedingly difficult. Nevertheless, existing models of air pollution/health damage relationships can be improved, extended, and tested against new data. Simplifying assumptions can be made more realistic, and other factors that modify the effects of air pollution can be added to the models. The annual expenditure of billions of dollars on control programs surely justifies these efforts.

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October 27, 1983

Mr. Tom Burack, Staff Assistant to
U. S. Senator Gordon J. Humphrey
United States Senate
Washington, D. C. 20510

Dear Tom:

Enclosed are copies of assorted correspondence dealing with the subject of aluminum, particularly aluminum in somewhat acidic water supplies, and its possible relationship to dementia and other neurological disorders.

While somewhat cumbersome to peruse, these materials provide a pretty clear picture of the current state of knowledge...

There is certainly more, and I would be happy to be of further assistance, at your convenience.

Sincerely,

Peter

Peter Allen

PA/vv
Enclosure
cc: Mr. J. Willcox Brown, Chairman, WSPCC
Mr. Dennis Lunderville, Chairman, N. H. Acid Rain Coordinating Committee

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April 8, 1982

Dr. D. Carleton Gajdusek, Chief
Laboratory of Central Nervous System Studies
National Institute of Neurological and Communicative
Disorders and Stroke
National Institutes of Health, U.S.P.H.S.
Bethesda, MD 20205

Dear Dr. Gajdusek:

My particular concern has been the possible health effects of aluminum in somewhat acidic water supplies. Data from a New England Water Works Association/Environmental Protection Agency water supply study, which became available recently, show some numbers comparable to your data for New Guinea published in Neurology (32:107-127, table 8).

I have taken the liberty to enclose copies of some of the data for New Hampshire supplies tested. Any comments or further investigation which you care to make would certainly be welcome.

Sincerely,

Peter Allen

Peter Allen, Ph.D.
Principal Planner
Water Quality Management Planning

PA/vv
Enclosures
4 Sheets: Raw + Treated H_2O Supplies / yel. highlighting

DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service

National Institutes of Health
Bethesda, Maryland 20205

April 28, 1982

MAY 6 1982

Peter Allen, Ph.D., Principal Planner
The State of New Hampshire
Water Supply & Pollution
Control Commission
Hazen Drive, P.O. Box 95
Concord, NH 03301

Dear Dr. Allen:

Thank you immensely for the interesting data you have sent to us. The thesis we are investigating is certainly based upon an environmental excess of metallic ions, especially aluminum, made hazardous, by exposure during infancy and childhood, in subjects who have had a secondary hypoparathyroidism, which has developed because of chronic deficiency of calcium and magnesium. Such secondary hypoparathyroidism which provokes idiosyncratic hypersensitivity to metal ions, would not develop, I suspect, in people using calcium- and magnesium-low drinking water if their food supply was largely imported from elsewhere.

Our foci of high incidence ALS and PD have developed in populations that had no food brought in from the outside.

I thank you immensely for your interest and for the valuable data you have brought to my attention.

Sincerely yours,

D. Carleton Gajdusek

D. Carleton Gajdusek, M.D.

DCG:vr

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May 7, 1982

Dr. D. Carleton Gajdusek, Chief
Laboratory of Central Nervous System Studies
National Institute of Neurological and Communicative
Disorders and Stroke
National Institutes of Health, U.S.P.H.S.
Bethesda, MD 20205

Dear Dr. Gajdusek:

Thank you for your informative response of April 28th. I agree that people would not normally suffer calcium and magnesium deficiencies with modern commerce compensating for local water conditions.

On the other hand, it is my impression that there are a number of ways in which deficiencies of these minerals could occur in some individuals. While the incidence would be small and the complexity of interpreting the situation would be great, I had wondered whether the possibility merited investigation. — I should have known [?] !

Sincerely,

Peter Allen

Peter Allen, Ph.D.
Principal Planner
Water Quality Management Planning

PA/vv
Enclosures

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Chief Engineer

Water Supply and Pollution Control Commission
Hazen Drive — P.O. Box 95
Concord, N.H. 03301

June 12, 1982

Dr. Donald R. McLachlan
Departments of Physiology & Medicine
University of Toronto
Toronto, Canada

Dear Dr. McLachlan:

For some time I have been delving into the literature on aluminum and the possible health effects of it in water supplies. Reports of your earlier work and your recent review, "Aluminum in Human Health", have been reviewed.

. One question which bothers me is enclosed. Perhaps you or an associate could address it? So far, no one has, and the lack of an answer leaves reason for continued concern about the possible health effects of aluminum in somewhat acidified water supplies, in my opinion.

Any assistance which you can provide would be gratefully appreciated.

Sincerely,

Peter Allen

Peter Allen, PhD.
Principal Planner
Water Quality Management Planning

PA/vv
Enclosure

The State of New Hampshire

Water Supply and Pollution Control Commission
Hazen Drive — P.O. Box 95
Concord, N.H. 03301

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A Question About Dialysis Dementia

According to the recent EPA draft Review (p. VI-9):

"Interestingly, although many chronic renal failure patients consume large amounts of aluminum - containing antacids, this syndrome is distinctly absent in non-dialyzed uremic patients, while exposure to repetitive hemodialysis for only 6 to 12 months may provoke this syndrome."

Why?

If antacid aluminum intake is 1000 mg/day or more and absorption is 10% or more, that's an uptake of 700 mg or more a week (from Gorsky, et al, 1979).

If dialysis treatment twice per week exposes blood to 300 l of dialysate, and if this contained 0.2 ppm aluminum, the blood would be exposed to about 60 mg a week.

Why may the latter "provoke this syndrome"?

Peter Allen, PhD.
Principal Planner
Water Quality Management Planning

1829-1979
TORONTO
GENERAL
HOSPITAL

101 College Street, Toronto [illegible]

ROOM: Eaton Wing N. 11-213

PHONE: 595-3592

July 5, 1982.

JUL 13 1982

Dr. Peter Allen, Ph.D.,
Principal Planner,
Water Quality Management Planning,
Water Supply and Pollution
Control Commission,
Hazen Drive - P.O. Box 95,
Concord, New Hampshire 03301
U.S.A.

Dear Dr. Allen:

Thank you for your recent letter concerning the problem of chronic renal failure and the consumption of aluminum. The answers to the questions that you have addressed to me cannot be given. There are many problems yet to be sorted out on the toxicity of aluminum and you are quite right in pointing out the difficulties. I have enclosed a paper which I recently wrote concerning the toxicity of aluminum and the evidence from animal studies. You might wish to obtain a copy of the Journal "Neurotoxicology" which was published by Pathotox Publishers and was devoted to the aluminum toxicity problem. There is an article there by Alfrey as well on the problem of renal related neurotoxicity of aluminum. Needless to say there are many unanswered questions concerning this problem and it would be a pity to become over-alarmed at this time but on the other hand, I feel that we cannot overlook the possible neurotoxic effects of this agent.

Thank you very much for your interest.

Yours sincerely,

D. R. McLachlan/kmc

D. R. McLachlan, M.D., F.R.C.P.(C),
Professor in the Departments of
Physiology and Medicine,
Faculty of Medicine,
University of Toronto

(dictated but not read)

DRM/kmc

150 Years of Patient Care, Teaching and Research

55

The State of New Hampshire

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June 16, 1983

Ken Kosik, M. D.
Ralph Lowell Labs
McLean Hospital
115 Mill Street
Belmont, MA

Dear Dr. Kosik:

Your interest in the effects of aluminum has been brought to my attention. For some time I have been concerned about the possible health effects of aluminum in water supplies.

This letter is to express my considerable interest in (but lack of resources for) the study of dementias and water supply. It is my impression that heredity studies have not been looking at water supplies...I agree with those who believe that "the answer is not in."

The enclosed copies of correspondence, etc., may be of interest.

Sincerely,

Peter Allen

Peter Allen, Ph.D.
Principal Planner

PA/vv
Enclosures
DR McLachlan, AGDD, resp 6/12 - 7/5/82
JM Elwood, resp 6/18 - 7/15/82
CS Cronan etc 6/25
Memo meeting DP Perl 9/2/82
DC Gajdusek 12/21
Memo meeting UNH 1/19/83

HARVARD MEDICAL SCHOOL

Ralph Lowell Laboratories
Mailman Research Center

McLEAN HOSPITAL
An Affiliate of Massachusetts General Hospital

McLean Hospital
Belmont, MA 02178

JUN 23 1983

June 21, 1983

Peter Allen, Ph.D.
Principal Planner
State of New Hampshire
Water Supply and Pollution
  Control Commission
Hazen Drive
Box 95
Concord, New Hampshire 03301

Dear Dr. Allen:

Thank you for your inquiry regarding our mutual interest in a possible association between the biological handling of aluminum and the development of dementia. I note in the enclosed correspondence that you have already contacted the two investigators who have made the most recent contributions in this area - Dr. Dan Perl and Dr. Carl Gajdusek. Except for the work of Dr. Gajdusek concerning the Parkinson-dementia complex, I am unaware of any definitive epidemiologic data that might address an association between aluminum and Alzheimer type dementia. Methodological considerations make the rigorous conduct of such studies exceedingly difficult. Currently, colleagues of mine are conducting just such a carefully designed prospective study in Boston. However, this study which will fill in many unanswered epidemiological questions is not designed to address aluminum exposure. I will detail some ideas for relevant studies at the end of this letter.

Our research concerns the cellular biology of aluminum toxicity. Aluminum administration to certain animals induces a histological lesion that bears some resemblance to the pathological picture one sees in Alzheimer's disease. The lack of identity with the Alzheimer type lesions has made this animal model somewhat controversial. We have strengthened the association between the animal model of aluminum toxicity and Alzheimer disease by finding a common enzymatic defect in the neurotransmitter synthesizing enzyme, choline acetyltransferase. This enzyme known to be deficient in AD is also markedly deficient in the aluminum intoxicated animals (Kosik, KS., et al., 1983, J. Neuropath. Exp. Neuro.).

In a similar vein, we have also addressed the mechanism by which the induced lesion occurs. The most prominent feature of aluminum toxicity is the massive accumulation of a cytoskeletal element known as neurofilaments within the neuronal cell body. We have found that unlike those toxins which result in the accumulation of neurofilaments in the axon, aluminum induced filaments do not accumulate as a result of a defect in their intracellular transport.

We have now begun to focus on the effects of aluminum on neurons growing in cell culture where we have exquisite control over their milieu. At this point, there is no available experimental data concerning how the neuronal membrane or any biological membrane handles aluminum. However, based on several recent in vitro studies, we have hypothesized a role for aluminum and calcium in which these ions working in concert or in the presence of a relative calcium deficiency can lead to the filamentous pathology associated with Alzheimer's disease. The complex relationship between aluminum and calcium has been noted in certain aquatic lifeforms in which high water aluminum levels prevent normal shell formation. Regarding your very germa~~i~~ne considerations of pH as an additional factor in the possible toxicity of a water supply, I am sure you are aware that as the pH becomes more acidic, aluminum is more easily solubilized.

Lastly, I might raise with you the valuable clue that Down syndrome patients provide. As you are probably aware, Down syndrome is clearly related to the presence of an extra chromosome known as chromosome 21. A very high percentage of Down syndrome patients develop after age 30 pathology indistinguishable from Alzheimer's disease. Some investigators have attempted to explain this relationship by searching for a chromosome 21 gene product that may directly relate to Alzheimer's disease. However, equally likely in these patients is a defective gene product involved in aluminum and calcium regulation. Many Down syndrome patients have been institutionalized in one place for the greater part of their lives which immediately obviates the population mobility problem of many epidemiologic studies. Water supplies to such patients particularly those in more rural settings are not likely to have undergone many of the changes in a mobile urban population. Thus, a comparative study of the incidence of dementia among this geographically restricted fairly well-defined population and geological features, e.g., aluminum, calcium, magnesium levels, in ~~or~~ the New England area would be very useful.

I would be happy to pursue further with you any of the epidemiological, clinical or cell biological topics I have raised in this letter.

Sincerely yours,

Kenneth S. Kosik

Kenneth S. Kosik, M.D.

KSK:mat

STATE OF NEW HAMPSHIRE

INTER-DEPARTMENT COMMUNICATION

DATE January 19, 1983

FROM Peter Allen
Principal Planner - WQMP

AT (OFFICE) Water Supply & Pollution Control Commission

SUBJECT January 19, 1983 U.N.H. Meeting on Aluminum in Water Supplies

TO Files

These notes record the gist of a meeting called at my request at the Water Resource Center to evaluate the feasibility of predicting past aluminum concentrations from other water supply historical data such as pH and alkalinity. Those present were: Prof. Gordon Byers, Chairman, WRC; Dr. Francis Hall, Hydrologist; Dr. Barry Lyons, Geochemist-Earth Sciences; Dr. James Weber, Chemist; Dr. Paul Bishop, Environmental Engineering; and myself.

Many of my expectations were reinforced by the group. The problem is a very complicated and difficult one.

However, if pH were accurately known, total aluminum concentrations could be predicted. Dr. Windsor Sung (in Environmental Engineering) is most experienced in use of this modeling.

All pH's may be errant. There's a good article in the November (November) or December 1982 issue of ES&T by James Kramer on pH chemistry and the use of old data.

Because of the many uncontrolled variables involved, any prediction will be rough at best. But the consensus was that it would be worth doing for public water supplies with reasonably adequate pH data.

Presumably any apparent relationship would be studied in much greater detail in resulting studies.

The group expressed willingness to serve in an advisory capacity. When and if the time comes to run the computer, Dr. Sung would be the best person to help with analysis of the pH's I pull together.

PA/vv
cc: Bernard Lucey, Water Supply
Prof. Gordon Byers, Water Resources Center

The State of New Hampshire

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Concord, N.H. 03301

August 10, 1983

The Honorable Olympia J. Snowe
United States House of Representatives
123 Cannon Office Building
Washington, D. C. 20515

Dear Congresswoman Snowe:

Thank you for scheduling the excellent August 8, 1983, hearing in Bangor on "Alzheimer's Disease: Is There an Acid Rain Connection?"

These comments are ventured to supplement and complement the presentations made there. The possibility that aluminum in water supplies could somehow be related to mental disorders has concerned me for sometime, and I strongly support the need for very careful and comprehensive research in this difficult area of inquiry. If I can be of any assistance to the Congress, please let me know.

a) Soluble Aluminum is sometimes found in somewhat acidic public and private water supplies occurring in granitic soils and rock formations which are naturally acidic. Aluminum can also be found in those public water supplies where alum (aluminum sulfate) is used in water treatment as a flocculant to precipitate out material suspended in the water.

Because no water quality standard has been established by E.P.A. for aluminum, it is not normally measured in water quality analyses; and information on its occurrence is not as great as we would prefer.

Acid rain, by increasing the acidity of runoff, can increase the solubility of aluminum, and thereby exacerbate what naturally occurs to some extent in somewhat acidic soils.

While Dr. DeBoni was correct when he stated that "Alzheimer's Disease existed long before acid rain" was recognized as a problem, corrosive/acidic water supplies are natural phenomena, which have only been aggravated by acid rain. Alum treatment has been done in some water supplies for many decades.

b) Nutrient Deficiencies were mentioned as a predisposing condition on Guam, New Guinea and the Kii Peninsula of Japan, especially the lack of calcium and/or magnesium. Apparently dairy products were not part of these diets until recent decades, and this change, rather than those mentioned in Bangor, is apparently an important factor related to the decreasing frequency of occurrence of Parkinsonism Dementia and ALS.

My inquiries find that the aged are less able to absorb calcium and are more likely to suffer a calcium deficiency, and substantial portions of the United States populace consume less than 70% of the Recommended Daily Allowance of calcium (42% of the population) and magnesium (39% of the population).

If nutrient deficiencies are possibly a precondition, epidemiological studies have to be very carefully conceived.

Interestingly, those parts of the country most insulted by acid rain are also those areas with acidic soils and waters which not only may have soluble aluminum; but which are relatively deficient in calcium and magnesium.

c) Recent findings in the literature on aluminum contradict quite a bit of earlier work, and careful review is necessary to sort out erroneous information which could be misleading.

d) The problem is not simple. Something peculiar happens in the diseased condition. If aluminum is part of the complex diseased condition, and if it is part of the cause, it must be because a certain form gets to the wrong place at the wrong time.

Humans normally ingest 5 to 50 milligrams per day of aluminum in their diet. Yet, a very few milligrams in the wrong place in the human brain may be extremely harmful.

No one can answer a question I have posed about why dialysis dementia may be related to the presence of aluminum in the dialysate but is not related to the much larger quantities of aluminum ingested and absorbed in antacids.

As long as that question cannot be answered, I believe that aluminum in water supplies should be carefully studied as part of the enviromental aluminum/dementia research effort.

e) Heredity studies of Alzheimer's Disease apparently have not looked for common environmental conditions, one of which might be aluminum in water supplies. I suggest that future efforts should include such avenues of inquiry.

f) A broad spectrum of diseased conditions is apparently involved in the various dementias and related disabilities. I, therefore, urge that the overall research effort should be extremely inclusive in scope.

Because 20% of 80 year-olds are diagnosed as demented, it is not accurate to state that 80% are unaffected. Dr. Perl reported that 15% of those on Guam not diagnosed as affected were found to have neurofibrillary tangles loaded with aluminum. The difficulty of diagnosis itself tells us how complicated the subject is.

Finally, every one of my close friends of about my age - (49) - are remarkably more forgetful than they used to be. If this is a diseased condition, the importance to humanity of such phenomena is staggering.

Again, if I can be of further assistance to your efforts, please let me know.

Sincerely,

Peter Allen

Peter H. Allen, Ph.D.
Principal Planner

PHA/mb

cc: Congressman Mario Biaggi
Senator George J. Mitchell
Senator Warren B. Rudman
Senator Gordon Humphrey
Congressman Norman E. D'Amours
Congressman Judd Gregg

Also JWB
WAH
DL
TN
RC
D Perl
WS.

ACID RAIN

The Impacts on New Hampshire

NEW HAMPSHIRE ACID RAIN
COORDINATING COMMITTEE

MAY 1983

The report was prepared by Peter H. Allen, Ph.D., Principal Planner, New Hampshire Water Supply and Pollution Control Commission, and reviewed by the technical advisory members of the New Hampshire Acid Rain Coordinating Committee.

ACID RAIN: THE IMPACTS ON NEW HAMPSHIRE

This brief summary of acid rain impacts on New Hampshire will first discuss documented effects followed by consideration of less well documented but important concerns; and, finally, there is a brief overview of their significance to the State.

Known as "The Granite State," New Hampshire is mostly composed of acidic bedrock, and relatively shallow, acidic soils are prevalent. Alkaline materials are inherently in short supply and less able to neutralize the incoming acidity as much as in many areas.

WELL DOCUMENTED EFFECTS UPON NEW HAMPSHIRE:

First, it should be stated that the acidity of precipitation in New Hampshire is unquestioned. The true average pH of 262 events measured at the Water Supply and Pollution Control Commission laboratory, 1972 - 1983, was 3.94. In 1981, when we were last able to look, the median sulfate loading in 18 wet deposition events in Concord was 41 Kg per hectare per year(1).

Aquatic Systems have been measured extensively. In a study since 1977 of 262 N. H. lakes and ponds, including some of our largest, the median alkalinity - or acid neutralizing capacity - was 5.6 (1). Responsible lake scientists have set an alkalinity of 10 or less as a measure of lakes vulnerable to acidification and loss of their sports fisheries(2). All of our remote, high altitude trout ponds measured since 1980 have alkalinities of less than 10, and 84 per cent of all lakes and ponds studied in recent years have alkalinities of 10 or less(1).

More than one-third of the remote trout ponds had dissolved aluminum levels (related to low pH) of 0.2 ppm or more, enough to damage brook trout reproduction(1).

A study of 94 northern New England lakes showed 85% were more acid now than when first measured several decades before(3).

Comparisons of water transparency in 214 N. H. lakes showed 110 were more transparent in recent studies than 30 - 40 years ago; 51 were less transparent and the remaining 53 had not changed more than 10 per cent(1). Acidification due to acid deposition is presently the most probable explanation. Planktonic growth in the water is less with low pH(1). Were it not for acid deposition, New Hampshire's rapid population growth and increased use of its lakes would be expected to make them less transparent than 30 - 40 years ago. We suspect that the effects of acidification and less planktonic growth at lower pH's is offset to a greater or lesser extent by increased nutrient input and planktonic growth stimulation related to increased human activity.

Our data base indicates substantial impacts upon aquatic systems. However, funds have not been available to improve our knowledge of conditions and, particularly, the rate of any changes occurring in these systems.

Visibility has declined throughout the Northeast. Decreasing visibility, caused by the scattering of light by small air borne particles, has been strongly associated in the Northeast with the occurrence of high concentrations of sulfate particles (4). Long-term studies showed a decrease of 10 to 40 per cent between 1953-55 and 1970-72 in non-urban locations in the northeast (4). In the summer, reductions of 25 to 60 per cent were reported. Visibility in recent years averaged less than 8 miles in the northeast (5).

Water Supplies in New Hampshire are often acidic. Nineteen of 25 dug wells tested had pH's below the EPA limit of 6.5(6). Because of their low pH's, many of our water supplies are corrosive. More than half of samples of water from ten public water supplies that was in household plumbing overnight had copper levels exceeding the EPA secondary standard of 1.0 ppm. Forty per cent exceeded the limit for iron, and 20 per cent exceeded the limit for lead(6).

Our data base is not adequate to evaluate the rate of any changes which may be occurring in water supplies. Funds have not been available for appropriate studies.

In acidic N. H. water supplies, aluminum often is found in solution in concentrations unfit for use in home dialysis treatment. Deionization and reverse osmosis treatments must be used to remove the aluminum before our water can be used as dialysate. Aluminum in dialysate has been correlated with dialysis dementia, which can be fatal in a matter of months.

Clear mountain springs seeping out of the moss high on a mountainside probably at times exceed EPA drinking water standards for [redacted] lead and other metals, based upon Camel's Hump studies in Vermont and on Mt. Moosilauke in N. H.(7)

Urban Runoff from acid precipitation is more toxic in N. H. than elsewhere. Our studies show unexpected amounts of lead, copper, zinc, etc., dissolved in acid runoff rather than suspended, as occurs with higher pH. The median value for lead in solution was at the EPA primary standard for drinking water(1). We must now consider buffering runoff, to precipitate metals, in addition to slowing it down to settle suspended materials in urban runoff treatment plans.

LESS WELL DOCUMENTED EFFECTS:

Human Health effects in New Hampshire are not well documented nor proven, however:

Airborne sulfate levels here, particularly in the summer, attain or approach levels where several adverse health effects upon sensitive parts of the population have been detected elsewhere, particularly among the elderly and persons with asthma(8).

A strong statistical association has been found between atmospheric sulfates and cancer mortality, cardiovascular mortality, infant mortality and total mortality. The probability of dying from air pollution in the north central and northeastern United States is about twice as high as elsewhere(8).

The possibility that aluminum in some water supplies could be related to health effects (dementia) among certain parts of the population - possibly some persons suffering deficiencies of calcium and/or magnesium - cannot be ruled out at this time(9).

Mercury and possibly other metals which have either been transported in atmospheric deposition or/and leached into acidic soil solution and runoff have accumulated in fish at times in sufficient levels to render their regular consumption dangerous(10).

Corrosive water supplies producing excessive lead concentrations in water which remained in the plumbing overnight could have undocumented health impacts.

Timber Productivity declines have not generally been documented in New Hampshire, however:

Red Spruce at high elevations in the northeast, including New Hampshire, has declined drastically in the last two decades. The spruce are growing in shallow soils where fog/cloud condensation adds a more severe burden of acid deposition which, evidence in Vermont indicates, may be related with the decline(11).

Effects upon somewhat deeper, lower elevation soils would be slower to appear and more difficult to detect at early stages. Evidence is gradually pointing toward the real possibility of a gradual long-term decline in growth and vigor of important timber species, including sugar maple, beech and yellow birch(11).

Aluminum in acidic soil solutions can reach concentrations found toxic to tree root growth in laboratory tests in Vermont(11).

Building Material Weathering due to acid deposition has been detected in New Hampshire, as well as elsewhere in the northeast. Calcium carbonate in limestone, marble, sandstone, mortar, cement, etc., is dissolved and converted to calcium sulfate and washes away.

Marble gravestones are conspicuously more eroded than granite ones in our cemeteries.

Wildlife Populations are affected to extents not well documented.

Aquatic insects growing in acidic waters can cause biomagnification f aluminum in feeding birds to the point which may reduce their eproductive ability(13).

Substantial accumulations of metals, on leaves from dry deposition and residue from evaporation, could possibly affect the health and reproductive ability of leaf-eating animals such as deer(14). There is currently an unexplained decline in deer populations in northern New England.

(Note: The long range transport of other air pollutants cannot neatly be separated from sulfuric and nitric acids. Mercury, for instance, is emitted in the smoke from coal burning.)

SIGNIFICANCE OF IMPACTS:

The potential impacts of acid rain in New Hampshire are vast:

Human Health should be of primary concern. The relationships between airborne sulfates and human health found elsewhere are of serious concern in New Hampshire.

Corrosive water supplies also pose a potential health impact of significance where lead is leached from the plumbing.

Aluminum in drinking water is of concern to some and merits careful study.

The potential health effects are ones which would be difficult to measure and evaluate. However, they could possibly have profound cost effects on public and private health care.

Public Perceptions of the State as a clean, healthy place to live, work and play are threatened by growing publicity of findings to the contrary due to the long range transport of air pollutants. People are beginning to worry about the effects upon them, their health and welfare, their land, their homes, and their investments.

Recreation and Tourism are the second largest industry in the State.

In FY 1982, tourism brought $762 million gross revenues into the state's economy, including $157.4 million to state and local revenues(15). Reduced visibility detracts from the appreciation of our scenery. Any impacts such as the death of many forest trees, such as red spruce, currently could detract from the aesthetic enjoyment of our forests, as would declines in productivity of our renowned fishing lakes and ponds and, possibly, bird and mammal life.

The total economic contribution of sport fishing in New Hampshire has been estimated at $86.4 million for 1978(16).

Reduced Timber Production would be of major impact to the State's economy. In 1980, the wood using industry paid $174 million in wages and contributed $351 million to the Gross State Product (17). Less vigorous trees not only do not grow as fast, but they are more vulnerable to damage by forest insects and diseases. The economics of timber production would become even less favorable for forest landowners. Declined production would gradually be reflected in less harvesting and less production of the wide variety of products of the wood using industries.

Weathering of Building Materials due to acid deposition, while it has not been measured in New Hampshire, can represent a very substantial cost.

No measure of the rate of weathering or the cost of damage due to acid deposition here is available, but the annual cost for the eastern U. S. has been estimated to be $13 billion(12).

Damage to irreplaceable historic structures and monuments can be immeasurable.

References:

1. Data of N. H. Water Supply and Pollution Control Commission. Dr. Peter H. Allen, P. O. Box 95, Concord, N. H. 03301.

2. Communication from Alan Van Arsdale, MA Dept. Environmental Quality Engineering.

3. Norton, S. A., R. B. Davis, D. F. Brakke. 1981. Responses of Northern New England Lakes to Atmospheric inputs of Acids and Heavy Metals. Completion Rept. Proj A-048 ME, U. ME Orono 90 pp.

4. Trijonis, J., and K. Yuan. Visibility in the Northeast: Long-Term Visibility Trends and Visibility/Pollutant Relationships. EPA - 600/3-78-975: Research Triangle Park, N.C. 1978. Ref In Northeast Damage Report.

5. Costle, D. M. Acid Rain! The Time To Act Is Now. Acid Rain Conference with the states, Springfield, VA, April 8, 1980.

6. Data from New England Water Works/EPA Study 1981-82 available at N. H. Water Supply and Pollution Control Commission.

7. Cronan, C. S. Solution Chemistry of a New Hampshire subalpine ecosystem: a biogeochemical analysis. Oikos 34:272-281, 1980 and unpublished report from Dr. Richard Klein, University of Vt. 1982.

8. Bridge, J. E. and F. P. Fairchild, Northeast Damage Report of the Long Range Transport and Deposition of Air Pollutants. Northeast Regional Task Force on Atmospheric Deposition. 1981, rev. 1982.

9. Information and correspondence in files of Dr. Peter H. Allen, N. H. Water Supply and Pollution Control Commission.

10. Studies have been mostly Canadian. The N. H. Pesticides Control Board checked mercury content of fish in the late sixties.

11. Unpublished report from Dr. Richard Klein, University of Vt. 1982

12. Tschirhart, 1980 Ref. In Northeast Damage Report.

13. Nyholm, N. E. Evidence of involvement of aluminum in causation of defective formation of eggshells and of impaired breeding in wild passerine birds. Environmental Research 26:363-371, 1981.

14. Lindberg, S. E., R. C. Harris, and R. R. Turner, Atmospheric Deposition of Metals to Forest Vegetation, Science 215:1609-1610, 1982.

15. Data from Division of Economic Development, Department of Resources and Economic Development, 105 Loudon Rd., Concord, N. H. 03301

16. University of New Hampshire study reported to Dr. Peter H. Allen by Leigh Welcome, N. H. Fish and Game Department.

17. Data from Division of Forests and Lands, Department of Resources and Economic Development, 105 Loudon Rd.

May 26, 1983

SYNOPSIS

(Key excerpts from the following report with page references to the full text of each section)

NORTHEAST DAMAGE REPORT
of the
Long Range Transport and Deposition of Air Pollutants

April 1981

Prepared for the Northeast States for Coordinated Air Use Management (NESCAUM) and the New England Interstate Water Pollution Control Commission (NEIWPCC)

INTRODUCTION

The following report has been prepared with the help of various members of the Northeast Task Force on Atmospheric Deposition. Members of the Task Force include state air and water pollution control agency staff appointed by the agency directors, as well as affiliate members from other state and federal agencies. The Task Force was formed at the request of NESCAUM and NEIWPCC to address the impacts of atmospheric deposition in the Northeast, control strategy alternatives, and future research needs.

DEPOSITION AND LONG RANGE TRANSPORT OF AIR POLLUTANTS

Atmospheric Deposition Processes (Page 3)

Because of their size, chemical nature, and prevalence, sulfur and nitrogen compounds are an integral part of atmospheric chemistry and are the main cause of acid deposition. Atmospheric deposition also includes other extremely harmful compounds, primarily organics and metals. Finally, sulfur oxides, nitrogen oxides and these other components of atmospheric deposition are subject to long range transport because of their existence as fine particles.

Emissions (Page 6)

The primary precursor pollutant to acid deposition, sulfur dioxide, is emitted in significantly larger amounts by midwestern states compared to the northeastern states.

Long Range Transport (Page 9)

The meteorological regime of the northeastern United States is particularly conducive to long range transport and deposition of pollutants emitted in the Ohio River Valley region. The maritime tropical air masses occurring in the summer bring high levels of sulfate into the

Northeast. The transport of sulfate has been verified by a number of independent observations using well documented sulfate episode data. Evidence exists to show the transport of other fine particles and pollutants into the Northeast region. This transport of fine particulate is interfering with the states' ability to meet mandated air quality goals.

Use of Regional Transport Models (Page 14)

While much in the way of a rigorous validation of all the regional transport models remains to be done, it seems reasonable to conclude that the EURMAP results often quoted by EPA in determining cross-regional transport are suspect.[1] Based on a limited review of available models, PNL and Fay models represent reasonable alternatives.[2]

AIR AND PRECIPITATION MONITORING

Regional and National Monitoring Networks and Results (Page 17)

Extensive data are available from large scale monitoring networks, and the state of monitoring technology has advanced so that the data can be combined. Review of the data shows widespread acid precipitation and pollutant deposition in the northeast region.

State Regulatory Agency Routine Monitoring Activities (Page 25)

Analysis of ambient sulfate data monitored by state air agencies shows that high sulfate levels exist across entire states at times when local sources of SO_2 and sulfates are lowest. Agency measurements of pH are limited, but substantiate the existence of acid precipitation in the region.

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[1] EURMAP is adapted for the U.S. from a model developed in Europe.

[2] PNL and Fay are Pacific NW Lab and Ohio River Basin models, respectively.

Special Air and Precipitation Measurement Activities (Page 29)

Extensive data are available from atmospheric measurements of transported pollutants and precipitation for the past 5 to 10 years. The monitoring technology has developed sufficiently so that data from a variety of independent monitoring networks can be compared. The data show that long range transport of fine particulates, especially sulfates, acid precipitation and dry deposition is being measured throughout the 8-state northeast region. The data record is sufficiently long and complete to say that the high sulfate concentrations and low pH values observed are consistent from year to year, and are not the result of unusual precipitation patterns in any one season.

REGIONAL IMPACTS OF ATMOSPHERIC DEPOSITION

General Extent of Regional Vulnerability (Page 32)

Due to weathering resistent bedrock geology, sensitive soils and water with extremely low buffering capacity, much of the northeastern U.S. is quite vulnerable to acid precipitation. Due to location in the transport path and local conditions, high elevations in the Adirondack Mountains of New York are especially vulnerable. Many streams, lakes and reservoirs in the region are very low in alkalinity and thus vulnerable to acidification. Fisheries managers in the region are faced with the knowledge that the ability of acid-sensitive fish to reestablish or continue self-sustaining populations could be jeopardized. Water supply managers are faced with the possibility that increases in treatment could be needed for many vulnerable waters before distribution to the public.

Terrestrial Ecosystems (Page 38)

Some types of heavy metals are accumulating in Northeast soils from atmospheric deposition. Other metals and some nutrients are being

Human Health and Welfare (Page 50)

The long range transport and atmospheric deposition of air pollutants are endangering human health and welfare in the Northeast, both indirectly and directly. Drinking water quality has been impaired by acid loadings which necessitate more treatment to reduce corrosivity and avoid the leaching of lead, copper, and other metals from distribution systems. Some metals, such as aluminum, have been leached into surface and groundwater supplies, and may have dire consequences for kidney dialysis patients if dialysate water is not adequately treated. Other metals and toxic organics deposited into lakes and ponds following long range transport have accumulated in fish tissue and have rendered the fish dangerous for human consumption.

Extensive data confirm that sulfates and other fine particles involved in atmospheric deposition are associated with direct effects on human health, from serious respiratory and cardiovascular diseases to death from cancer. Adverse health effects have been identified at levels well below the annual sulfate levels found in the Northeast, sulfate levels that are attributable in large part to long range transport into the region. The high levels of sulfates in the Northeast definitely contribute to a significant number of premature deaths, and the probability of dying from air pollution-related diseases is significantly higher in the Northeast.

SUMMARY AND CONCLUSIONS

The Northeast is subject to long range atmospheric transport, and receives considerable levels of air pollutants from outside the region. The deposition of these pollutants has complex and far reaching consequences. Information on long range transport, deposition, and the subsequent damage to the Northeast (has been) presented in this report.

leached from soils by acid precipitation, as soil leaching chemistry has changed from carbonate to sulfate based and microbial soil action has decreased. Much of the acid load on high altitude forest is in the form of fog, and forest productivity in some areas has decreased over the past 14 years.

Aquatic Ecosystems (Page 40)

As pH in lakes, streams and ponds is being lowered, loss of fish, and the interference with reproduction of fish and amphibians is occurring across the Northeast particularly at high elevations where natural buffering capacities are especially low. Additional changes in water chemistry due to the leaching of aluminum from soils or the deposition of metals such as lead and cadmium are also posing a danger to aquatic ecosystems.

Materials (Page 4)

Buildings and monuments in the Northeast, made of stone, masonry, and metal, are deteriorating due to the deposition of acid rain and particulate pollutants. The damage in many historical structures is especially serious, and now appears to be occurring at an accelerated pace.

Visibility (Page 46)

Visibility in the Northeast is being reduced, especially during summer months. This reduction is primarily due to light dispersion caused by the long range transport of sulfate particles, and is exacerbated by the high relative humidity in the region. The greatest reduction in visual range occurs during the most damaging time of the year for the tourist industry in New England. Light dispersion also reduces available sunlight for solar energy production and plant photosynthesis, and may have other climatological effects.

DOCUMENT: 850-22/012

June 19-21, 1983
New England Governors and
Eastern Canadian Premiers
Eleventh Annual Conference

Onzième conférence annuelle
des Gouverneurs de la Nouvelle-
Angleterre et des Premiers Ministres
de l'est du Canada
19-21 juin 1983

RESOLUTION 11-4

ACID RAIN

WHEREAS, an action program to control acid rain and the long range transport of air pollutants, and a Transboundary International Accord, as called for in Resolution 10-9 adopted by the Tenth Annual Conference, have not yet been achieved; and

WHEREAS, continuing efforts are being directed toward the development of cost-effective technologies for controlling acid precursor emissions; and

WHEREAS, accumulating evidence, such as contained in the Final Work Group Reports of the United States-Canada Memorandum of Intent of 1980, supports the development of a Transboundary International Accord; and

WHEREAS, the responsible management of air emissions is a continuing concern;

NOW THEREFORE BE IT RESOLVED that the Governors and Premiers call for reductions of acid precipitation precursor emissions in order to work actively towards a target loading of no more than 20 kilograms per hectare per year of wet sulphate in precipitation in New England and Eastern Canada; and

BE IT FURTHER RESOLVED that the Governors and Premiers call for federal action and financial support to develop and demonstrate cost-effective retrofit technologies for emissions control, in addition to applying currently available abatement technologies; and

BE IT FURTHER RESOLVED that the Governors and Premiers call for the development of a long range energy policy for Eastern North America which considers the impact of future increases in energy demand on pollutant emissions levels; and

.../2

BE IT FURTHER RESOLVED that the Governors and Premiers recall the urgency and necessity for our national governments to make all the efforts required in order to reach a mutually acceptable Transboundary International Accord clearly in the bi-national interest. We urge our respective federal governments now to fully accept their responsibilities to reach agreement in this area; and

BE IT FURTHER RESOLVED that the heads of the environmental protection agencies in the United States and Canada be requested to meet with the Conference next year.

ADOPTED BY THE 11th CONFERENCE OF NEW ENGLAND GOVERNORS AND EASTERN CANADIAN PREMIERS

Premier James M. Lee
Cochairman

Governor William A. O'Neill
Cochairman

Jun 21.83
Date

June 20, 1983
Date

Statement of Brendan J. Whittaker, Secretary
Vermont Agency of Environmental Conservation
Before
U.S. Senate Committee on Environment and Public Works
Public Hearing on Acid Rain, Senator Humphrey Presiding
Concord, New Hampshire, 10/14/83

The Vermont Agency of Environmental Conservation testified before this Committee about 2 years ago at hearings held by Senator Stafford on the pending reauthorization of the Clean Air Act. It was Vermont's view at that time that the most serious weakness in the act was its inability to deal with the problem of long range transport of air pollutants, particularly the transformation product of sulfur dioxide.

The Agency presented evidence that sulfate particulate, originating beyond our borders, was frequently transported into rural Vermont on prevailing winds at concentrations more representative of heavily polluted industrial areas. It was pointed out that, although there is a large amount of uncertainty in the health affects area, a number of reputable researchers were finding serious adverse health effects associated with these kind of sulfate concentrations. We cited thoroughly documented evidence that sulfate particulate causes dramatic reductions in visibility and is responsible for about half of the total extinction of light in the atmosphere. We stated that sulfate is the primary acidifying component of rainfall in Vermont and that our rainfall was many times more acidic than could be accounted for by natural sources, and that large sections of our state were underlain by soils and bedrock with limited capacity to neutralize this acid deposition.

We cited research from botanists at the University of Vermont that indicated that our high elevation forests were receiving even greater acid loadings and that the red spruce at these high elevations were dying. Acid rain, in possible combination with heavy metals, was a suspected contributing factor.

Finally, we argued that when all the damages and potential damages associated with the long range transport of sulfur compounds are considered, there was more than sufficient evidence to initiate control strategies without further delay. This conclusion was supported by a comprehensive report issued by the National Academy of Sciences later that year.

A lot has happened in the acid rain field in the two years since that original testimony. West Germany and Canada are making serious commitments to reduce their sulfur emissions because of perceived damages from acid rain. In our own country, a recent flurry of proposed acid rain legislation in both houses of Congress gives us cause for optimism as many of these bills call for the kind of 50% reduction in Eastern SO_2 emissions we think is necessary to demonstrate a positive affect on our environment.

At the same time serious questions have been raised regarding the true extent of damages attributed to acid rain, the influence of natural vs. manmade sources, the importance of local vs. distant sources, and the linearity of the relationship between sulfur emissions and sulfur deposition. A considerable amount of research has been conducted in the State of Vermont during the past several years and some of it has direct bearing on these important questions.

What I would like to do today is bring you up-to-date on some of this most recent research and how it has influenced the State's position on this issue.

Let me summarize in advance that everywhere we look we see that damages and potential damages are not less serious but more serious and widespread than we originally anticipated. Our recent research confirms that these damages result from distant manmade sources, and from Midwestern coal burning sources in particular. Our original conviction is stronger than ever: Namely that when all of the damages are considered, including not only effects on aquatic and terrestrial systems, but also the very serious degredation of visibility and the potential effects on human health, there is more than sufficient evidence to initiate stringent regional control measures without further delay.

In the area of aquatic resources, 5 of our lakes are considered critically acidic exhibiting negative alkalinities. Twenty-four others are considered extremely sensitive with alkalinities of less than 2.5 mg/l (milligrams per liter). An additional 65 exhibit alkalinities of less than 12.5 mg/l and are considered moderately sensitive.

A fisheries survey conducted on 29 of these lakes, mostly in the critical and extremely sensitive categories, revealed that two (2) contain no fish of any species. Seventeen have been routinely stocked with brook trout which are among our most acid tolerant species. The extent to which these stocked fisheries are maintained by stocking alone is uncertain.

As a group, these extremely sensitive and critically acidic lakes compose 2,532 acres of surface area. They tend to be small, oligotrophic, high elevation and remote. At the present time liming is definitely not considered to be a cost effective means of eliminating damages, but we will be watching these lakes very carefully in the future. Our concern is that a number of the sensitive ones may be hanging on the borderline and may not be able to tolerate continued acid loadings without going critical.

The potential acidification of our streams is another area of concern which we plan to look at in more detail in the very near future. We have already witnessed drops of two (2) full pH units in several central Vermont streams during the spring runoff period. The West River System in Southeastern Vermont is considered an important potential spawning habitat for the Atlantic Salmon Restoration Program. Springtime pH measurements of 4.95 and 5.20 on two of the West River tributaries indicate that this area's full potential as atlantic salmon spawning habitat may already be threatened. In light of the considerable time, effort and money being devoted to the Salmon Restoration Project, this is a most discouraging finding.

In addition to our monitoring activities on the State's surface waters, we have also been looking very carefully at the effects of sulfate particulate on one visibility. We have recently completed a regression study comparing daily sulfate particulate concentrations measured during the summer of 1982 and concurrent airport visibility observations in Burlington, Vermont. The results indicate that during non-rainy, non foggy periods (about 90% of the time), the combined effect of sulfate and relative humidity accounted for 87% of the variation of light extinction in the atmosphere. Sulfate alone accounted for 84% of this extinction. To put this in somewhat simplier terms, the average visual range at the Burlington Airport was about 22.5 miles. Had there been no sulfate in the air that summer, the visual range would have been close to 33 miles, an increase of about 45%. On July 17, 1983, when the sulfate climbed to 35 ug/m^3, the visibility dropped to less than 5 miles.

The sulfate samples used in this visibility analysis were collected at the Proctor Maple Research Center in Underhill, Vermont as part of a larger cooperative study between our Agency and Dr. Kenneth Rahn of the University of Rhode Island. Dr. Rahn, you may recall, was among the first to suggest the importance of local sources to sulfate concentrations in the Northeast. His earlier work was based on the ratio of manganese to vanadium in the air at Narragansett, Rhode Island, compared to the ratio of these elements in different source regions. He has since expanded his regional tracer technique so that it now includes seven (7) elements, and with these, he is able to distinguish the aerosol originating from six (6) different regions of North America.

The most common elemental signature in Underhill during the summer of 1982 was from local New England sources which dominated about 40% of the time. When this occurred the air was generally sulfate free - with an effective sulfate concentration of only about 3 ug/m^3. Dr. Rahn also detected a distinct Midwestern signature, with heavy influence of coal burning. This midwestern signature, while only dominant about 25% of the time was associated with an effective sulfate concentration of 21 ug/m^3, seven (7) times the sulfate concentration associated with local New England sources.

I think that these results are extremely significant and would urge those critics who were quick to interpret Dr. Rahn's earlier Narragansett study as evidence that New England's sulfate results from local sources, to take a close look at the Underhill results. Midwestern sources are the dominant cause of sulfate concentrations in Northern Vermont.

Perhaps the most dramatic recent research into the effects of long range transport in Vermont is being conducted in our high elevation forests by Drs. Richard Klein and Hub Vogglemann of the University of Vermont Botany Department. Dr. Klein is here today so I'll let him fill you in on the details and just say in summary that their most recent research seems to strongly support their earlier suspicions that the combined effect of acid rain and certain metals may be an important causal factor in the decline of these high elevation forests. The decline does not appear to be limited only to red spruce at the highest elevations but seems to include a number of other species at much lower elevations.

In a very close parallel to the trend of our own research, Dr. Klein and Dr. Vogglemann tell me that the more they look the more the evidence tends to suggest a cause and effect relationship, and the stronger the indication that damages are more serious and widespread than originally anticipated.

Seeing this kind of trend does not exactly make us want to sit around and wait for 10 more years of research, and we strongly support the efforts of your Senate Environment and Public Works Committee to initiate control strategies designed to reduce Eastern sulfur dioxide emissions by about half - something on the order of 10 to 12 million tons. A 50% reduction in deposition seems to be well supported by the first National Academy of Science Report and by the MOI Effects Work Group as what's needed to protect moderately sensitive aquatic areas from further degredation. The more recent National Academy of Sciences Report on Atmospheric Processes indicates that a general reduction in emissions is likely to result in an equivalent reduction in deposition - that the chemistry is roughly linear.

Where and how these reductions should most efficiently be achieved is a much more complicated matter. There may be some important differences between the sources and source regions that influence wet vs. dry deposition, but I think one thing Dr. Rahn's work indicates is that if we wish to reduce dry sulfate concentrations in Northern New England, it would be most effective to control sources in the industrial midwest. This also makes sense from a cost efficiency standpoint, as the largest, most poorly controlled sources - the ones where we can get the biggest reduction bang for the buck also tend to be located in the Midwestern region.

I don't mean to suggest that the entire problem is caused by coal burning Midwestern utilities alone. All sources of sulfur contribute incrementally to the problem at some location. What I am suggesting is that the most effective way to reduce deposition in sensitive areas and to do it for the lowest total cost is to reduce emissions from the largest sources in the region where they happen to be located.

We sympathize with the kind of economic and employment disruptions this type of emissions reduction strategy would cause, and for this reason I foresee that some sort of cost sharing mechanism may ultimately be necessary. I think that we could support some sort of cost sharing compromise provided the reduction in emissions was adequate and permanent and provided that the costs were distributed in an equitable manner. New Englanders already pay a considerable premium for their cleanly produced electricity. Care must also be taken that clean states like Vermont are not penalized in terms of our future growth potential, simply because we have no present sulfur emissions to use as offsets to accommodate future growth.

I'm sure these details can and will be worked out in a reasonable manner and we're hopeful that the apparent momentum in Congress will result in an equitable legislative means of solving this serious national problem sometime in the very near future.

State of Vermont

AGENCY OF ENVIRONMENTAL CONSERVATION

Montpelier, Vermont 05602
Department of Water Resources
and
Environmental Engineering

Department of Fish and Game
Department of Forests, Parks, and Recreation
Department of Water Resources & Environmental Engineering
Natural Resources Conservation Council

December 1, 1983

Senator Gordon Humphrey
U.S. Senate Office Building
Washington, D.C. 20510

Dear Senator Humphrey:

At acid rain hearings you held in Concord, New Hampshire on October 14, 1983, I presented the testimony of Brendan J. Whittaker for the Vermont Agency of Environmental Conservation. You requested prints of several slides displayed at the conclusion of the testimony. Enclosed are those prints and a brief summary of their significance. I am very sorry for the delay.

More recently, we have obtained 72 hour backward trajectories for the air arriving in Underhill, Vermont on July 14, 1982 and on July 17, 1982 (the dates of lowest and highest sulfate concentration respectively). These trajectories (also enclosed) were calculated by the ARL-HITTM (Hefter) model. The Hefter model ordinarily calculates the prior locations of air parcels arriving at 6 hour intervals at a given destination for four time periods each day. Unfortunately, only two time periods were available for July 17, 1982, but I believe the available trajectories are more than adequate to indicate the distinctly different origin of air parcels reaching Northern Vermont on the two dates, and to further confirm Dr. Rahn's conclusion that the July 17, 1982 episode was clearly of Midwestern origin.

I hope these enclosures will be of some assistance in your efforts to secure an equitable legislative solution to this serious problem.

Sincerely,

Richard A. Valentinetti

Richard A. Valentinetti, Director
Air and Solid Waste Programs

RAV:lah

Enclosures

cc: Senator Robert Stafford

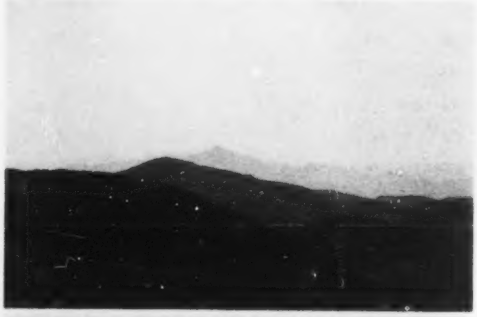
The attached prints were reproduced from slides presented by the Vermont Agency of Environmental Conservation at acid rain hearings held by Senator Humphrey in Concord, New Hampshire on October 14, 1983. Vermont's testimony focused on the results of air and precipitation monitoring at the Proctor Maple Research Center in Underhill, Vermont during the summer of 1982. This monitoring was conducted in part by the PMRC staff, the Utility Acid Precipitation Study Program, Dr. Kenneth Rahn of the University of Rhode Island Graduate School of Oceanography, and the Vermont Air Program.

On the basis of detailed elemental analysis of air samples, Dr. Rahn has developed a 7 element tracer system which can be used to indicate the region of origin of the aerosol arriving in Underhill each day, and to estimate the effective sulfate concentration associated with each region. The highest effective sulfate concentration of any region was that associated with an elemental signature from the industrial Midwest.

The Vermont Air Program has utilized the daily Underhill sulfate values and visibility observations at the Burlington International Airport as part of a regression analysis of light extinction. The analysis indicated that during non-foggy, nonrainy periods (about 90% of the time), sulfate particulate accounted for 84% of the variance of the extinction of light in the atmosphere.

The following photographs document the arrival of one particular sulfate episode in Northern Vermont, an episode which Dr. Rahn's technique indicates was clearly of midwestern origin, and during which an extremely acidic rain event was recorded.

The view is from the top of Mr. Mansfield looking south. In the foreground is a southwestern ridge of Mt. Mansfield, followed by Bolton Mountain at a distance of about 5 miles. Behind Bolton and slightly to the right is the relatively sharp peak of Camel's Hump, about 15 miles away. Behind and slightly to the left of Camel's Hump is Mt. Ellen, about 35 miles away.

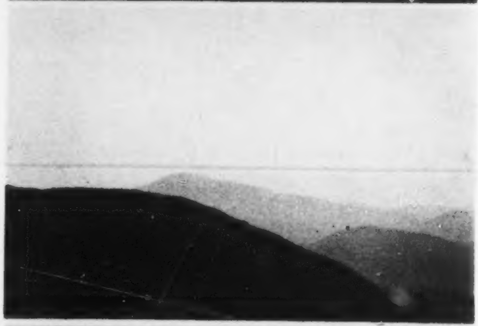


July 14, 1982

Measured Sulfate concentration in the air is less than 1 ug/m3.

Burlington Airport Visibility averages 35 miles.

Dr. Rahn's analysis indicates no detectable presence of Midwestern aerosol in Underhill.



July 15, 1982

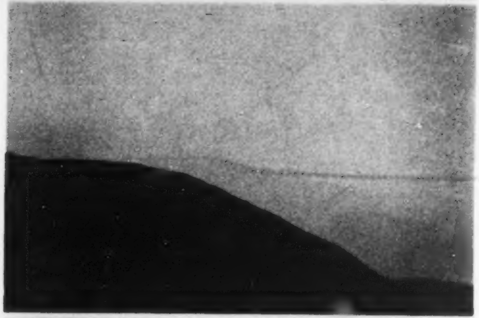
Measured Sulfate concentration in the air has risen to 6 ug/m3.

Burlington Airport Visibility averages 13 miles.

Dr. Rahn's analysis indicates 60% of the estimated Sulfate is from Midwestern sources.

Camel's Hump Mt. is barely visible.

Mt. Ellen is gone.



July 16, 1982

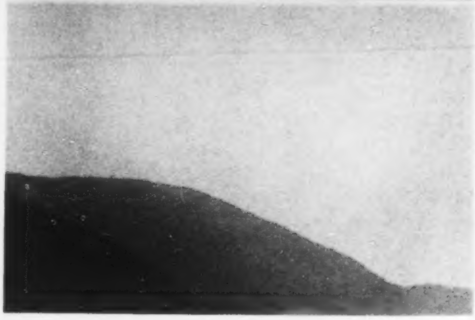
Measured Sulfate concentration in the air has risen to 13 ug/m3.

Burlington Airport Visibility averages 6.8 miles.

Dr. Rahn's analysis indicates 97% of the estimated Sulfate is from Midwestern sources.

Bolton Mt. is barely visible.

Camel's Hump Mt. is gone.



July 17, 1982

Measured Sulfate concentration peaks at 35 ug/m3.

Burlington Airport Visibility averages less than 5 miles.

Dr. Rahn's analysis indicates 100% of the estimated Sulfate is from Midwestern sources.

Bolton Mt. is gone.

Later that night it rained in Underhill.

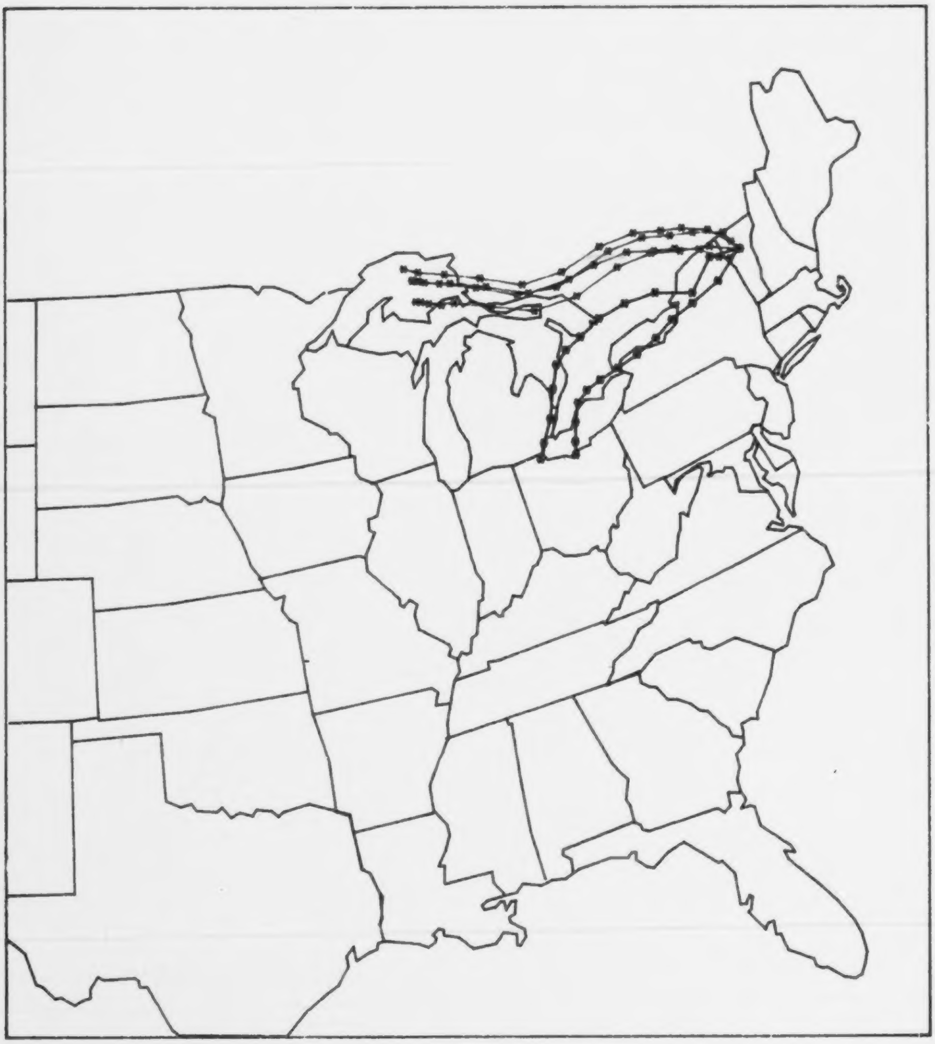
The pH (3.47) and Sulfate ion concentration (146 umoles/liter) represented the lowest pH and the highest Sulfate concentration of any rain event at Underhill that summer.

AIR MASS TRAJECTORIES ARRIVING AT UNDERHILL VT.
Calculated by HEFFTER TRANSPORT MODEL (ARL-HITTM)

72-hr Backward Trajectories
for JULY 14 & JULY 17 1982

6 Hr time interval between points

—— —— July 14 (SO4<1 ug/m3) ———— July 17 (SO4=35 ug/m3)
1 AM, 7 AM, 1 PM, 7 PM 1/ Eastern Standard (EST) 1 AM, 7 AM 2/



1/ Refers to the three lines at the top of the map.

2/ Refers to the lower two lines.

A COOPERATIVE STUDY OF THE EFFECTS OF ACID RAIN ON WATER SUPPLIES

Floyd B. Taylor
New England Water Works Association
850 R. Providence Highway
Dedham, Mass. 02026

Environmental Protection Agency
(Task Force Project 4-1)

ABSTRACT

Although there are in the literature a few scattered references about the effect of acid rain on water supplies there has until now been no thorough investigation of the subject. The EPA-NEWWA cooperative research project is providing accurate modern and historical data to evaluate what the effect may be. Samples of source raw and finished water have been collected from over 300 surface and ground water supplies in the New England States, New York, New Jersey, Pennsylvania, West Virginia, Virginia and North Carolina. These are analyzed at EPA laboratories. Historical records have been obtained dating back to 1886.

Acid rain has the potential for dissolving harmful elements from soils and also, indirectly, from water supply distribution systems. As soils have a capacity for altering the character of acid rain through buffering identification of causual relationships is not an easy matter. To aid in approaching this problem, indices of water supply sensitivity and aggressiveness have been utilized. By use of these indices and reliable chemical data an assessment of water supply characteristics is being accomplished for both current and long term conditions.

While solution products of acid rain in the water supply sources studied do not significantly exceed EPA Primary Drinking Water Regulations, a signifigant number of aluminum tests showed levels of that element which could be of concern to patients using kidney dialysis. There seems to be reasonable basis for attributing some of the aggressiveness of New England water supplies to acid rain. Quantification remains a problem. A case history of long term trends is presented.

A COOPERATIVE STUDY OF THE EFFECTS OF ACID RAIN ON WATER SUPPLIES

(Task Force Project 4-1)

Floyd B. Taylor
New England Water Works Association
850 R. Providence Highway
Dedham, Mass. 02026

IMPORTANCE

This project is the major, EPA funded study of the impact of acidic deposition on water supplies used by the public, and in some cases by individuals, as sources of drinking water. It is a project which deals with three highly important questions. 1) Does acid rain contribute to or cause adverse effects upon human health through drinking water drawn from surface and ground water sources, 2) Does acid rain contribute to or cause indirectly adverse effects upon human health through corrosion or dissolution of distribution system materials thereby adding to the water supply harmful substances which were not in the source of supply and 3) Does acid rain cause a significant part of the large economic losses attributable to corrosion of water systems? Some idea of the magnitude of the latter is seen in estimates that nationally such losses top $1,000,000,000 per year. A specific case in point is a single industrial plant in Fitchburg, Massachusetts where annual costs for replacing damaged plumbing are over $50,000.

Another important aspect of the project is that it is adding significantly to the data base being used by EPA in its national assessment of current, surface and ground water quality.

SPECIFIC HYPOTHESES

(1) Observed occurrences of harmful elements in water supplies may be caused to some degree by acid precipitation through direct or indirect contribution of such elements to the water supply sources.

(2) Acid rain may contribute to the corrossivity of surface and ground water supplies thereby becoming a causual or contributing factor in
    (a) Indirectly causing the occurrence of harmful elements in tap water
    (b) Contributing significantly to the economic losses incurred in operation of water distribution systems.

(3) There has been a notable trend over time in certain water supply constituents attributable to acidic deposition.

TECHNICAL APPROACH

Data for testing the above hypotheses is coming from accurate analyses of current water supply quality and from historical records. The project is divided into three phases: 1) visits for tests, samples and historical data to 123 surface water supplies in New England and northeastern New York; completed, 2) retesting and analyzing 40 of the first phase surface waters and visits to 100 ground water sources in the above study area; completed and 3) visits to 65 ground water supplies in the Applachian states of Pennsylvania, West Virginia, Virginia and North Carolina and in the Pine Barrens and coast of New Jersey; in progress.

Evaluation of the modern and historical data is being approached from a water supply engineering perspective which differs in some respects from the perspective of the ecologists who are studying the effects of acid rain on lake, land and forest ecosystems. The water supplier deals with the problems of water quality at a single or at a relatively few points where water of composite quality is processed; the ecologist has to deal with changes over large areas of land or water. The water supply operator has since 1914 had standards by which to evaluate the effect of his product on human health. Thirdly, the water supplier has since 1936 had indices for determining the potential impact of his product on distribution system materials. The earliest were the Langelier Index (LI) and the Ryznar or Stability Index (SI) and most recently the Aggressive Index (AI). A fourth index not developed by the water supply industry but one found most useful to this study is the Calcium Saturation Index (CSI). Tables for interpreting the four indexes are as follows:

Calcium Saturation Index

CSI Values	CSI Classification
<1	Terrain is most stable and not susceptible to change.
1-2	Possibly susceptible to change.
2-3	Probably susceptible to change.
3-4	Susceptible to change.
4-5	Highly susceptible to change.

Corrosive Character of a Water Supply	Langelier Index	Aggressive Index	Stability Index
Highly aggressive	<-2.0	<10.0	>8
Moderately aggressive	-2.0 to<0.0	10.0 to<12.0	7-8
Nonaggressive	≥0.0	≥12.0	<7

As extensive historical data on drinking water quality dating back to 1886 were discovered, a thorough investigation was made of changes in analytical methods from that time to the present for many constituents among which the following are most important: pH, alkalinity, calcium, sulfate, nitrate, total dissolved solids and hardness.

RESULTS

Some, selected results from the survey are presented in the following tables and figures which deal with health aspects, indices of stability and indices of aggressiveness or corrosivity. Table 1 shows concentrations of toxic substances in surface drinking water sources visited during Phase I.

Table 1. Record of Drinking
Water Quality, Phase I of N.E. Study
of 123 Surface Water Supplies
Raw and Finished Water

Element or Compound	MCL* (mg/l)	No. of Tests (N)	Analytical Results-N Tests		
			Range	Mean	No. Tests $>$ MCL*
Arsenic	0.050	259	<0.005-0.095	<0.005	~~0~~1
Barium	1.000	261	< 0.20-0.53	<0.20	0
Cadmium	0.010	262	<0.002-0.018	<0.002	1
Lead	0.050	262	<0.005-0.205	<0.007	2
Mercury	0.002	261	<0.0005-0.0049	<0.0006	1
Selenium	0.010	259	<0.005-0.024	<0.005	1
Aluminum	None	261	<0.1-0.5	<0.1	~~0~~
Nitrate	10.0	259	<0.3-60.0	<0.58	1

Table 2 shows AI, CSI, LI and SI values and other data on ground water supplies on Cape Cod and in New Jersey.

Table 2. Indices of Corrosivity, Terrain
Stability and Other Data for 10 Massachusetts
and New Jersey Ground Water Sources

Number	pH	Solids**	Calcium**	Alkalinity**	AI	CSI	LI	SI
1	4.11	37	1.0	<0.1		9.39	-9.39	22.89
2	4.45	72	4.5	0.71	5.35	6.52	-6.57	17.60
3	4.10	29	0.9	<0.1		9.46	-9.46	23.01
4	4.51	46	1.7	3.82	5.72	6.20	-6.23	16.98
5	4.26	27	0.8	<0.1		9.21	-9.21	22.68
6	6.40	181	11.0	22.6	9.19	2.78	-2.90	12.19
7	6.92	85	7.7	36.8	9.77	2.23	-2.29	11.50
8	5.92	43	1.3	6.0	7.21	4.49	-4.89	15.70
9	5.66	48	1.0	3.0	6.53	5.16	-5.57	16.80
10	5.72	45	1.2	2.0	6.50	5.20	-5.58	16.88

*EPA Maximum contaminent level. **mg/l

Table 3 illustrates the depth of historical information which was located in records of the Lawrence Experiment Station for all the water supplies surveyed in Massachusetts. For the purpose of illustration the water supply serving the cities of Salem and Beverly, namely Wenham Lake, was selected.

Table 3. Historical Data From Water Supply of Salem Beverly, Massachusetts

Year	Corrected* Alkalinity***	Corrected** pH	Calculated Calcium***	CSI	LI	SI
1936	16.2	6.7	8.34	2.47	-2.47	11.64
1940	16.2	6.6	8.34	2.57	-2.58	11.76
1945	13.1	6.5	6.67	2.86	-2.86	12.22
1949	16.2	6.6	8.90	2.54	-2.54	11.68
1955	12.1	6.8	9.17	2.46	-2.46	11.71
1960	11.1	6.9	10.56	2.33	-2.33	11.56
1965	10.1	6.8	12.51	2.40	-2.40	11.60
1970	14.2	6.7	13.62	2.32	-2.32	11.33
1975	14.2	6.9	12.23	2.17	-2.17	11.24
1980	17.1	7.3	11.12	1.73	-1.73	10.75

Year	Hardness***	Year	Hardness***
1888	19	1935	29
1890	25	1940	30
1895	31	1945	24
1900	22	1949	32
1905	22	1955	33
1910	23	1960	38
1915	27	1965	45
1920	25	1970	49
1925	28	1975	44
1930	30	1980	40

*Corrected according to Kramer equation; Geochemistry Report 1981

**Corrected according to Kramer equation; Acidification of Aquatic Systems:A Critique of Chemical Approaches; ES&T, 1982.

***mg/l

Figures 1 and 2 show LI, SI, CSI and AI values derived from analyses of 123 surface water supplies surveyed in Phase I of the study.

FIGURE 1. COMPOSITE CALCIUM SATURATION INDEX & AGGRESSIVE INDEX VALUES for all states in the survey.

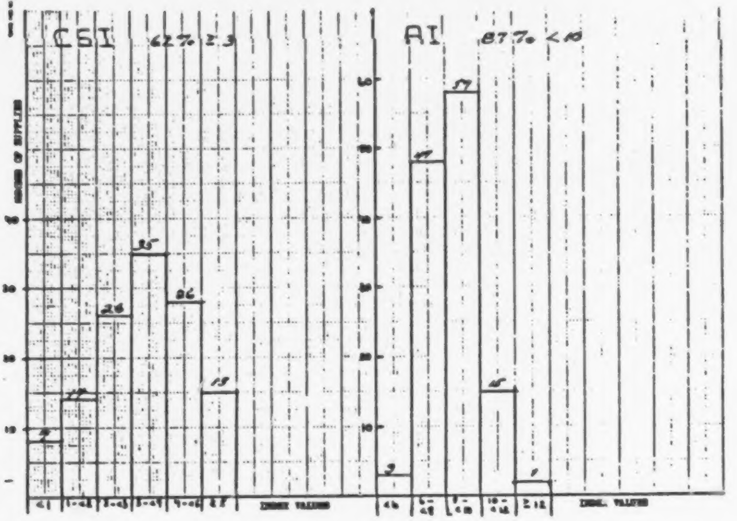
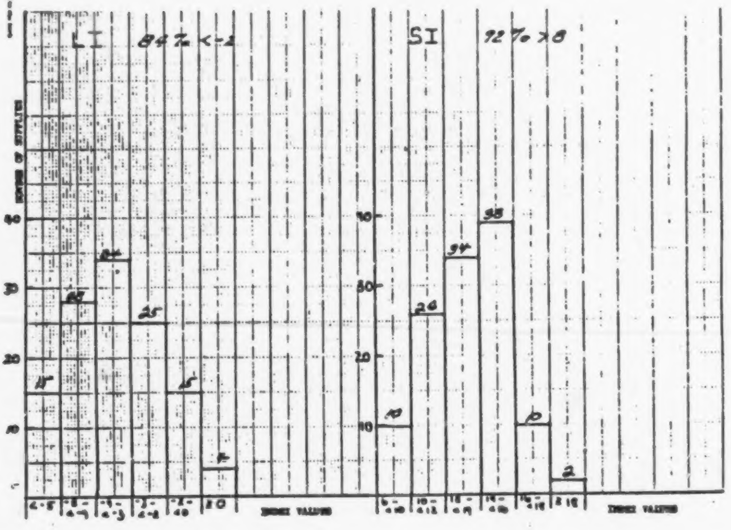


FIGURE 2 COMPOSITE LANGELIER INDEX & STABILITY INDEX VALUES for all states in the survey.



DISCUSSION

Data of Table 1 show that surface source water supplies as tested in Phase I of the study would not endanger human health when ingested. Additional testing would be required in the few cases of exceeded MCL's to determine average values of the metals shown. Although there is no MCL for aluminum, and this element has not been implicated in water-borne illness through ingestion, there is data to indicate that aluminum is a hazard to patients using kidney dialysis. New Hampshire has set a limit of 10 ug/l for aluminum content of dialysates. One outbreak of dialysis encephalopathy has been documented in which the dialysate contained 200 ug/l of aluminum. Seventy two (72) of the Phase I surface water samples contained aluminum equal to or in excess of 100 ug/l; of these twenty-eight (28) showed aluminum equal to or greater than 200 ug/l.

A picture of the sensitivity and corrosiveness of the raw water of Phase I surface waters is shown by data contained in Figures 1 and 2. Referring to the tables of interpretation given on the second page data from Phase I is summarized as follows:

Index	Value	Category of Interpretation	% Supplies in Category
CSI	> 3	Susceptible or highly susceptible to change	62
LI	< -2	Highly aggressive	84
AI	< 10.0	Highly aggressive	87
SI	> 8	Highly aggressive	92

A somewhat different interpretation of CSI values suggested by Kramer, 1976; Conroy et al 1974 is that surface waters having a CSI of < 3 are generally stable to acid precipitation and those with CSI values 4 to 6 are unstable. The data presented above show that a high proportion of New England surface waters are in the borderline or unstable condition.

The picture of the corrosive character of these waters is even more clear. Here, according to proven methods of interpretation of AI, LI and SI values, 84 to 92 percent of the supplies are highly aggressive. The remainder fall mainly in the moderately aggressive class. All this is brought into sharper focus by showing what an aggressive, unadjusted water supply does to distribution system materials. A case in point is the Quabbin supply of the Boston Metropolitan District Commission. Boston has a high percentage of lead service lines and plumbing. During 1976-1977, prior to pH adjustment, 443 tap water samples from the Boston and Somerville distribution systems showed a mean lead concentration of 0.079 mg/l and in 195 or 44% of the samples lead exceeded the 0.050 mg/l MCL of EPA. According to the National Academy of Science there is no safety factor in the EPA standard. The current values for CSI, LI, AI and SI for the Quabbin system are 4.18, -4.22, 7.50 and 14.74 respectively. It may be shown from our historical data that these indices were similar in 1976.

The ground water situations described by the data in Table 2 are most interesting. Here we have seen the highest and lowest indices values of the project. The first seven supplies are drawn from the sands of New Jersey and the last three from Cape Cod. The nature of aquifers along the Atlantic Seaboard is mainly silica sand which is not noted for its buffering capacity.

Finally, the historical data as shown in Table 3. For the case chosen there does not appear to be much change over the period 1936-1980 in the indices of stability and corrosion. If anything they seem to have improved somewhat. While there is an apparent increase in hardness from 1888 to 1980 it may be due to the change from the soap method for determining hardness to EDTA method in 1956 and to atomic absorbtion in 1973. The relative accuracy of these procedures is being evaluated.

In summary. Adverse health effects of water supply sources from the surface are not supported by the data except that for patients on kidney dialysis aluminum could be a factor. The highly corrosive nature of the great majority of the surface and ground sources herein reported upon and the demonstrated capacity of such waters to dissolve harmful elements from pipe materials, indicate a problem area. While it cannot be quantified at this point of the study, it highly likely that acidic deposition exacerbates this condition. The historic data from the supply cited suggest that there has not been a trend in water quality due to acid rain or, possibly that acidic deposition dates back further than is commonly supposed.

CONCLUSIONS

(1) Adverse effects of acid rain on human health through ingestion of surface supply source waters was not demonstrated but data show that unadjusted aluminum content in a number of supplies could be a problem to patients on kidney dialysis.

(2) While quantification remains to be established, it is reasonable to assign some part of the highly corrosive nature of New England waters to acidic deposition.

(3) Historical data, as demonstrated in the case described, show that highly aggressive waters have been encountered for a long time.

REFERENCES

Impacts of Airborne Pollutants on Wilderness Areas Along the Minnesota-Ontario Border, Edited by Glass, G. E. and Loucks, O. L.; EPA-600/3-80-044 May 1980

Interim Primary Drinking Water Regulations, EPA. Federal Register, V.45 No. 168 August 27, 1980.

A New Index for Determining Amount of Calcium Carbonate Scale Formed By a Water, Ryznar, V. W.; JAWWA, 36:472, April 1944

DELIVERABLES

Participation on panel on Health Effects of Acid Rain, APHA Annual Meeting, Montreal, Canada, October 1982 talk entitled, A U. S. Position.

Update on Acid Rain: Paper presented at the 100th Anniversary Conference of the New England Water Works Association, September 21, 1982. Pending publication in the March issue of the NEWWA Journal.

Impact of Acid Rain On Meeting EPA Drinking Water Regulations: Paper scheduled for presentation at the 1983 Annual Convention of the American Water Works Association.

RELATIONSHIP TO OTHER WORK

This project was designed to obtain as much information as possible on both current quality data and historical data which would be useful in national assessments of the effects of acidic deposition, and to other researchers who need accurate information. A case in point is the provision to researchers at the University of Massachusetts data for their evaluation of conditions in the Commonwealth.

ACTIVITIES

Frequent appearances have been made before public and small gatherings to describe the progress and findings of the work. The project director is a member of the Northeast Regional Task Force on Atmospheric Deposition sponsored by the New England Interstate Water Pollution Control Commission. The Acid Rain Research Team members for Connecticut and New Hampshire are members of legislative committees dealing with acid rain.

SUPPORT

EPA: FY 1981-82, $100,000; FY 1982-83, $100,000. NEWWA $10,000.

PERSONNEL

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There are also thirteen field engineers working in as many states.
Maine - Porter Hennings, Portland.
Massachusetts - James Matera, West Boylston
Connecticut - Frederick Almquist and Alexander Minkus
New Hampshire - Clarence Ferry, Concord.
Rhode Island - John J. Collins, Coventry
Vermont - John Richards, South Hero
New York - Dr. George Symons, Larchmont
New Jersey - John Wilford, Groveville
Pennsylvania - Dr. Charles Cole, Middletown
West Virginia - Hugh Hetzer, Kirkwood, Pa.
Virginia - Alfred Paessler, Richmond
North Carolina - Ralph Buelow, Marble

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ACID RAIN, 1983

WEDNESDAY, NOVEMBER 2, 1983

U.S. Senate,
Committee on Environment and Public Works,
Washington, D.C.

The committee met, pursuant to notice, at 10 a.m., in room SD-406, Dirksen Senate Office Building, Senator Robert T. Stafford (chairman of the committee) presiding.

Present: Senators Stafford, Chafee, Symms, Durenberger, Humphrey, Randolph, Bentsen, Burdick, Moynihan, Mitchell, and Baucus.

OPENING STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator **Stafford**. The Committee on Environment and Public Works will please come to order.

We note we are somewhat overcrowded this morning. We regret we do not have a larger committee hearing room available, but we politicians always prefer to see a slightly overcrowded room to one that is nearly empty.

Welcome to the hearings today. The subject of today's hearing is what is popularly known as acid rain. It is the first hearing on the subject to be held this year in Washington. Field hearings have been held earlier, however, in Minneapolis, Minn., and Concord, N.H.

We had originally planned to hold 2 additional days of hearings on the 8th and 10th, but scheduling difficulties have forced us to postpone those until later this year or, if the Senate keeps to its current proposed schedule, early in the next year.

Although these two hearings and possibly one or two others may be necessary, I, for one, do not anticipate any need for more than a limited number. Acid rain is not a subject which is new to this committee.

Today's hearing focuses on some scientific aspects of acid rain and its control. Except for our first witness, who will be the distinguished minority leader and Senator from West Virginia, Senator Byrd, the witnesses are scientists.

The first two witnesses are here to describe the recent report of the National Academy of Sciences' study and the manner in which it was prepared.

The second set of scientists are here to offer some criticisms of the Academy report.

A third pair will describe the impacts which acid rain may be having on forests and aquatic ecosystems.

All in all, these witnesses will make for a full day. So, I would like to proceed as soon as possible after by distinguished colleague and partner over many years, the ranking minority member, Senator Jennings Randolph, has made his opening statement.

OPENING STATEMENT OF HON. JENNINGS RANDOLPH, U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator RANDOLPH. Thank you very much, Mr. Chairman.

It has been well over a year since the members of our committee conducted intensive hearings on acid rain and associated issues. I welcome the opportunity to review with you and others perhaps new, at least additional, scientific developments that have to do with the causes and, we will say, the cures, of acid rain.

I especially am delighted that we can welcome our colleague from West Virginia, Senator Byrd, the able minority—I just started to say majority because I look forward to that.

Senator STAFFORD. Do not erase that mistake from the record.

Senator RANDOLPH. I wanted to imply that it could take place.

Senator STAFFORD. I am glad you said "could."

Senator RANDOLPH. Senator, we know of your intense interest and concern, and your commitment to doing constructive work in connection with the subject of acid rain.

There has been much divisiveness in connection with proposals to reduce sulfur emissions that relates to the lack of what we call a scientific consensus on the causes of acid rain, its effects, and how these might be reduced.

We are reminded that in 1980, the Congress directed a 10-year scientific study of acid rain matters. In the 97th Congress we again took action. I proposed legislation to accelerate these studies so that we could expedite our consideration of this environmental problem.

It is important that the members of the committee, aided by our witnesses, periodically review what progress is being made in what we call the scientific community.

However, it is not the only component of the overall issue that we on the committee must address. There are questions of equity and there are questions of cost as we consider what type of acid rain control programs should be undertaken. Acid rain is a problem, we generally accept that even though the degree of the seriousness may vary from State to State and from member to member in the Senate.

In West Virginia, as Senator Byrd well knows, we are concerned about the effect of acid rain on our streams and forests. Do not forget that we are a State of recreation, of woodlands, and of projects that seek to bring our recreational advantages to the attention of the country.

A recent newspaper report referred to acid deposition in my home county and the inability of fish to give in some of our beautiful streams. At the same time, we are concerned that a control program could be instituted that might be irreparable in its damage to our coal industry. We make no mistake in stating that, and the many thousands of persons who depend on this industry for livelihood. We have over 40,000 of our miners without jobs, and these are West Virginia miners, not from other States.

Any acid rain program that encouraged fuel switching in its early stages or failed to provide for regular review and adjustment could cause further unemployment and, certainly, a disruption in our coal markets.

These are not the inevitable consequences of a realistic sulfur reduction effort.

I am encouraged, as others are, that since last year the range of control proposals has broadened. This makes it possible that a more equitable solution can be found. This will not happen until acid rain is recognized as a national problem. I require that the national solutions be a part of the program. No single State nor small group of States must be asked, Mr. Chairman, to bear this financial and social burden.

I would not advocate delay in addressing this issue for I believe that it is possible to bring about a fair and equitable means of reducing acid rain. We cannot, however, be successful in our efforts by pitting State against State and region against region, and industry against industry. I am hopeful that the testimony we receive, especially from our first witness, the minority leader, will go into efforts beyond just the hearing stage today and try to bring this matter into what we call focus so that we may act as a committee and possibly the Congress.

Thank you.

Senator STAFFORD. Thank you very much, Senator Randolph.

Senator Mitchell, do you have an opening statement?

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you, Mr. Chairman. I will be brief in the interest of hearing from the witnesses.

I commend you, Mr. Chairman, and Senator Randolph for the scheduling of this hearing. I do not recall the exact number but I believe this is the 9th or 10th day of hearings that we have had on this particular subject, surely making it one of the most "heard" subjects with which this committee has dealt in many years.

I think there is a growing recognition that, as the distinguished former chairman of the committee has just indicated, this is a national problem of serious dimension which requires a national solution.

I think it is significant that in the 2 years which have elapsed since I first introduced legislation to deal with the problem the focus of debate has shifted away from whether we should do anything to what it is we should do. That is a very major and, I believe, significant step forward in the debate.

It was almost exactly a year ago, Mr. Chairman, that this committee voted by a margin of 15 to 1 in favor of legislation that would have produced a reduction in sulfur dioxide emissions in the Eastern United States of 8 million tons over a 12-year period.

Since then, substantial additional scientific information has been presented. It has been mixed, but on balance it is consistent with the scientific information that existed prior to then and that is, it overwhelmingly demonstrates the need for action now to deal with this serious national problem.

Much has been made of the question of equity. We have to be fair, it has been said over and over again. I could not agree more. And fairness begins with recognizing the fact that there are millions of people in this country who have already paid the price of clean air in their State and pay the price every day in very high rates for electricity because their utilities have installed pollution control equipment and because their utilities burn high-cost, low-sulfur fuels, who are nonetheless receiving pollution in the form of acid deposition that originates elsewhere, in regions where the cost of electricity is much less.

It is much less in those regions because comparable equipment controlling pollution has not been installed and high-sulfur, low-cost fuels are being used.

There is nothing fair about that, and fairness begins with recognition of the fact that this is a serious national problem which requires a serious national response.

I commend you, Mr. Chairman. I look forward to the testimony of the distinguished minority leader and of the other witnesses who are here today. It is my hope that this committee will move swiftly to take up this matter and bring it to the vote here in the committee, get it to the floor of the Senate, and bring it to a vote there.

There has been much debate. I think the time for everyone to stand up and be counted on this issue is upon us.

Thank you Mr. Chairman.

Senator STAFFORD. Thank you very much, Senator Mitchell.

Senator Baucus, do you have any opening statement?

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator BAUCUS. Thank you, Mr. Chairman.

Mr. Chairman, I have a prepared statement I would like to submit for the record.

Senator STAFFORD. Without objection, it will appear in the record in full.

Senator BAUCUS. In the meantime, Mr. Chairman, I would like to join Senator Mitchell and, I think, other members of the committee in recognizing that this is a problem we have to solve immediately.

I might add, Mr. Chairman, that from the perspective of the West, my State of Montana, we strongly feel that a solution here is not a national task. We feel that we are very much contributing to a solution of the problem in producing low-sulfur coal; in producing coal that can be used in other parts of the country, and we feel that a national tax which might benefit some parts of the country would very severely disadvantage the Western States who produce low-sulfur coal.

So, any solution we come up with—and we should come up with one very quickly—is one which should not unfairly disadvantage and discriminate against some Western States.

[Senator Baucus' prepared statement follows:]

SENATOR MAX BAUCUS
ENVIRONMENT AND PUBLIC WORKS COMMITTEE
NOVEMBER 2, 1983

MR. CHAIRMAN, MEMBERS OF THE COMMITTEE, TODAY BEGINS YET ANOTHER SET OF HEARINGS DEALING WITH THE QUESTION OF ACID RAIN. ACID RAIN IS NOT A NEW PHENOMENON. THE OCCURENCE WAS FIRST MEASURED IN GREAT BRITAIN MORE THAN ONE HUNDRED YEARS AGO.

ACID RAIN IS A PROBLEM

WHAT IS NEW IS THAT IT IS A PROBLEM REACHING CRISIS PROPORTIONS IN THIS COUNTRY. IT IS ONE WHICH WARRANTS THE UTMOST ATTENTION BY BOTH THIS COMMITTEE AND THE ENTIRE CONGRESS. I, FOR ONE, AM ON RECORD STRONGLY IN SUPPORT OF FINDING A SOLUTION. AT THE SAME TIME, I HAVE BECOME DEEPLY CONCERNED THAT THE DIALOGUE CONCERNING THIS SOLUTION CLASHES WITH THE INTERESTS OF THE WEST.

INGREDIENTS FOR ACID RAIN SOLUTION

IT IS CRITICAL THAT THE BOTTOM LINE FOR THIS COMMITTEE BE THAT WE FIND A MEANS TO CONTROL POLLUTION WHICH CAUSES ACID RAIN IN THE LEAST EXPENSIVE, MOST EXPEDITIOUS AND EQUITABLE WAY. IT IS MY DESIRE TO WORK WITH ALL MEMBERS OF THIS COMMITTEE AND , IN PARTICULAR, WITH THOSE FROM THE NORTHEAST WHERE THE DESTRUCTION IS THE GREATEST, AS WE WORK TO FIND THE SOLUTION TO THIS PROBLEM. AT THE SAME TIME, I DO NOT BELIEVE THAT WE CAN IGNORE THE VERY REAL CONCERNS OF THE EFFECTS OF AN ACID RAIN CONTROL PROGRAM ON JOBS. I BELIEVE WE NEED TO CONFRONT THIS PROBLEM OF JOBS AS DIRECTLY AS WE APPROACH THE QUESTION OF POLLUTION CONTROL. IN

PROTECTING THE LOSS OF JOBS WHICH MAY COME ABOUT DUE TO AN ACID RAIN CONTROL PROGRAM WE SHOULD LOOK TO HOW WE HAVE DEALT WITH THESE PROBLEMS IN THE PAST. NEARLY EVERY ADMINISTRATION AND CONGRESS SINCE 1932 HAS COME UNDER PRESSURE TO ASSIST THE CITIZENS OF APPALACHIA AND OTHER AREAS WHERE JOBS WERE BEING ERODED. THE CREATION OF THE APPALACHIAN REGIONAL COMMISSION IS ONE OF THE GREATEST EXAMPLES IN THE COUNTRY WHERE WE'VE DIRECTLY CONFRONTED THE SOCIAL POLICY QUESTIONS.

IN 1977, HOWEVER, CONGRESS REVERSED NEARLY 35 YEARS OF BIPARTISAN PRECEDENT. BOWING TO PRESSURES FROM SPECIAL INTEREST GROUPS, CONGRESS AMENDED SECTION 111 OF THE CLEAN AIR ACT. THIS SECTION DEALING WITH THE FEDERALLY ESTABLISHED EMISSION STANDARDS FOR NEW SOURCES TOOK THE UNPRECEDENTED STEP OF NOT ONLY REQUIRING THAT NEWLY CONSTRUCTED ELECTRIC POWER PLANTS MEET THE EMISSION LIMITS ESTABLISHED IN THE EPA'S NEW SOURCE STANDARD, BUT THAT IT DO SO VIA TECHNOLOGICAL MEANS, I.E. SCRUBBING.

THIS THINLY VEILED ATTEMPT TO PROTECT HIGH SULFUR COAL PRODUCERS IN ONE SMALL PART OF THE COUNTRY HAS NOT ONLY NEEDLESSLY INCREASED THE EXPENSE OF REDUCING SULFUR EMISSIONS FROM NEW POWER PLANTS, BUT IT ALSO HAS APPARENTLY EXACERBATED THE ACID DEPOSITION PROBLEM IN THE EASTERN UNITED STATES.

ANY ACID RAIN SOLUTION WHICH CONTINUES TO RELY UPON THIS MISGUIDED THINKING WILL CONTINUE NOT TO BE IN THE NATIONAL INTEREST. WE CAN NO LONGER AFFORD NOT TO LOOK AT LEAST COST STRATEGIES SUCH AS THE USE OF LOW SULFUR COAL AND OTHER INNOVATIVE TECHNOLOGIES, ALONG WITH SCRUBBERS TO MEET OUR AIR QUALITY OBJECTIVES.

AT THE SAME TIME, I BELIEVE THAT BY CONFRONTING THE ACID RAIN PROBLEM WITH A FLEXIBLE APPROACH, UNFAIR TAXES CAN BE AVOIDED. IT IS IMPERATIVE THAT EACH SOURCE HAVE FLEXIBILITY TO DETERMINE THE MOST COST EFFECTIVE MEANS TO ADDRESS THE PROBLEM. IN TURN, THOSE WHO BENEFIT FROM THE REDUCTIONS PAY FOR THE REDUCTIONS.

I WILL NOT SUPPORT A NATIONAL TAX. IT IS UNFAIR TO A STATE SUCH AS MONTANA WHERE THE COST OF PROTECTING THE AIR QUALITY OF THE "BIG SKY," AS MONTANA IS CALLED IS ONE THAT IS PROTECTED BY THE STATE CONSTITUTION.

MAINTAINING AIR QUALITY IN MONTANA DOES NOT COME WITHOUT SACRIFICE. MONTANA POWER COMPANY HAS RECENTLY DEDICATED TWO NEW COAL FIRED POWER PLANTS AT AN ESTIMANTED PLANT COST OF $1.4 BILLION. $500 MILLION OR 35% OF THIS COST WAS FOR AIR QUALITY FACILITIES AND RELATED TECHNOLOGICAL NEEDS.

MONTANA IS PAYING ITS FAIR SHARE TO PROTECT THIS COUNTRY'S AIRSHEDS. I CAN NOT SUPPORT A TAX AND WILL FIGHT TO PROTECT MONTANA'S INTERESTS.

BAUCUS POSITION

IT IS CRITICAL THAT THIS CONGRESS MOVE SWIFTLY TO SET A POLICY IN PLACE TO REDUCE ACID FORMING EMMISSIONS TO PROTECT THE FRAGILE ECOSYSTEM OF NEW ENGLAND, THE ENTIRE EAST AND CANADA. AT THE SAME TIME, THIS POLICY MUST NOT CALL FOR INEQUITABLE TAXES AND FORCE WRONGHEADED MANDATORY SCRUBBER PROGRAMS. I WANT TO WORK FOR THE SOLUTION NOT AGAINST THE SOLUTION, BUT IT MUST BE FAIR.

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator **STAFFORD**. Thank you very much, Senator.

Senator Durenberger?

Senator **DURENBERGER**. Mr. Chairman, I do have a statement, but I would defer. I would defer to the time of the minority leader and I look forward to his testimony.

[Senator Durenberger's prepared statement follows:]

STATEMENT BY
SENATOR DAVE DURENBERGER
ACID RAIN HEARINGS
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
NOVEMBER 2, 1983

THANK YOU, MR. CHAIRMAN.

LAST WEEK, I HAD THE OPPORTUNITY TO INTRODUCE AN ACID RAIN BILL OF MY OWN. IT HAS BEEN REFERRED TO THIS COMMITTEE FOR CONSIDERATION. IN PREPARING THAT BILL, WHICH INTRODUCES SOME NEW CONCEPTS TO THE ACID RAIN DEBATE, I FOUND MYSELF CHALLENGED BY A FEW BASIC QUESTIONS WHICH I THINK ALL MEMBERS OF THE COMMITTEE WILL BE FORCED TO RECONSIDER AS WE PREPARE TO REPORT CLEAN AIR ACT AMENDMENTS TO THE FLOOR. AS A NEW MEMBER, I HAVE NOT PREVIOUSLY MADE A STATEMENT IN THE COMMITTEE ON THE SUBJECT OF ACID RAIN. SO THIS MORNING, I WOULD TAKE A MOMENT OF THE COMMITTEE'S TIME TO REVIEW THOSE BASIC QUESTIONS AND TO SHARE, BRIEFLY, THE CONCLUSIONS THAT I HAVE COME TO.

THE FIRST QUESTION IS WHETHER WE AS A NATION SHOULD MAKE SUBSTANTIAL REDUCTIONS IN THE EMISSIONS OF POLLUTANTS WHICH ARE KNOWN PRECURSORS OF ACID DEPOSITION. THE WITNESSES HERE THIS MORNING WILL UPDATE US ON THE SCIENCE OF EMISSIONS AND DEPOSITION, BUT I THINK THE OVERWHELMING WEIGHT OF THE EVIDENCE COLLECTED BY THIS COMMITTEE AND OTHERS OF THE CONGRESS OVER THE LAST SEVERAL YEARS POINTS IN A CLEAR DIRECTION. IF WE ARE TO PROTECT NATURAL RESOURCES -- PARTICULARLY AQUATIC RESOURCES -- ON WHICH THE PEOPLE OF THIS NATION PALCE A VERY

HIGH VALUE, WE WILL NEED TO MAKE SUBSTANTIAL REDUCTIONS IN SULFUR DIOXIDE EMISSIONS AT AN EARLY DATE.

THERE IS NO MAGIC NUMBER. BUT THE RESOURCES SENSITIVE TO ACID DEPOSITION AND DAMAGED, OR POTENTIALLY DAMAGED IF TRENDS ARE NOT REVERSED, ARE LOCATED ACROSS THE ENTIRE CONTINENT. AND A LIMITED PROGRAM, OR A TARGETED PROGRAM, WILL SIMPLY NOT BE SUFFICIENT. I AM NOW ON THREE DIFFERENT ACID RAIN BILLS -- CALLING FOR 8, 10 AND 12 MILLION TONS OF REDUCTIONS. NUMBERS IN THAT RANGE ARE NECESSARY BECAUSE THE RESOURCES WE SEEK TO PROTECT ARE NOT CONCENTRATED IN A SMALL REGION OF THE NATION.

THE SECOND QUESTION IS WHETHER OR NOT WE NEED A FINANCING SCHEME AS PART OF THE PROGRAM WE ADOPT. I LOOK AT THE MEMBERSHIP OF THIS COMMITTEE AND I DON'T EXPECT THAT FINANCING PLANS WILL BE A POPULAR PROPOSAL AT THE TIME OF MARKUP. BUT I WILL PRESS FOR ONE, PARTLY BECAUSE I THINK IT WILL BE NECESSARY TO GET A BILL THROUGH THE CONGRESS AND PARTLY BECAUSE I THINK THAT A TAX WHICH SPREADS THE COST OF A CONTROL PROGRAM IS THE ONLY FAIR APPROACH.

CONTROL REQUIREMENTS CANNOT BE EVENLY APPLIED TO EVERYONE. AS A PRACTICAL MATTER WE WILL NOT GO TO EVERY SOURCE OF SULFUR DIOXIDE EMISSIONS IN THE NATION, OR A REGION OF THE NATION, AND REQUIRE EACH TO MAKE A 40% OR 50% REDUCTION. IT WOULD NOT BE COST EFFECTIVE. WHAT WILL IN FACT HAPPEN IS THAT A LIMITED NUMBER OF SOURCES WILL BE REQUIRED TO MAKE VERY SUBSTANTIAL REDUCTIONS -- CLOSER TO 90% -- WHILE OTHERS FACE NO REQUIREMENTS AT ALL. THE TYPE OF INDUSTRY, THE AGE OF

THE PLANT, THE IMPACT ON JOBS, THE AVAILABILITY OF A CONTROL STRATEGY -- ALL OF THESE FACTORS WILL DICTATE THAT CONTROL REQUIREMENTS WILL APPLY IN VERY DIFFERENT WAYS AT VERY DIFFERENT SOURCES. AT LEAST, THEY SHOULD IF WE ARE TRYING TO MAXIMIZE THE BENEFIT THAT WE GET FOR THE DOLLARS WE INVEST.

BUT A STRATEGY THAT SELECTS A FEW PLANTS IN A FEW INDUSTRIES AND MAKES THOSE PLANTS AND THEIR CONSUMERS BEAR ALL OF THE COST IS NOT FAIR. THERE ARE VARIOUS WAYS TO SOLVE THE FAIRNESS PROBLEM. I KNOW THAT THE BILL REPORTED LAST YEAR CONTEMPLATES AN EMISSIONS TRADING SCHEME, FOR INSTANCE. I WOULD SIMPLY RECOMMEND TO THE COMMITTEE THAT WE DO IT IN A MORE STRAIGHTFORWARD WAY WITH A TAX AND TRUST FUND THAT ALL CAN EVALUATE BEFORE THE LEGISLATION IS PASSED.

IF ONE AGREES THAT A FINANCING SCHEME WILL BE NECESSARY, THE THIRD QUESTION BECOMES WHAT KIND OF TAX MECHANISM WE SHOULD USE. I WAS ONLY ABLE TO IDENTIFY THREE ALTERNATIVES. DOLLARS FROM THE GENERAL FUND RAISED BY EXISTING TAXES. AN ENERGY OR BTU TAX WHICH HAS BEEN PROPOSED IN A BILL ON THE HOUSE SIDE. AND AN EMISSIONS TAX. I CHOSE THE EMISSIONS TAX IN MY BILL FOR TWO SIMPLE REASONS.

FIRST, IT GIVES CREDIT FOR WHAT HAS ALREADY BEEN DONE BY MANY TO REDUCE AIR POLLUTION. MY STATE AND ITS ELECTRICITY CONSUMERS HAVE INVESTED $300 MILLION IN SULFUR DIOXIDE SCRUBBERS. A SUBSTANTIAL INVESTMENT. AN ELECTRICITY TAX OR GENERAL TAX USED TO FINANCE CONTROL TECHNOLOGY IN SOME OTHER STATE WOULD MAKE THEM PAY TWICE. UNDER AN EMISSIONS TAX, THEY WILL MAKE A CONTRIBUTION BECAUSE WE STILL HAVE

EMISSIONS IN MINNESOTA, BUT THE RATE OF THE TAX WILL BE SUBSTANTIALLY LESS AS A RESULT OF THEIR PREVIOUS INVESTMENT IN CONTROLS.

SECOND, AN EMISSIONS TAX ALLOWS US TO GO BEYOND THE ELECTRIC UTILITY INDUSTRY TO SPREAD THE COST OF THE SOLUTION TO OTHERS WHO ARE CONTRIBUTING TO THE PROBLEM. MY BILL WOULD COVER SULFUR DIOXIDE AND NITROGEN OXIDE EMISSIONS FROM ALL MAJOR STATIONARY SOURCES AND WOULD INCLUDE A TAX ON NITROGEN OXIDE EMISSIONS FROM MOBILE SOURCES.

A FOURTH QUESTION IS HOW TO SELECT THE SPECIFIC INVESTMENTS OR RETROFITS THAT WILL BE NECESSARY TO ACHIEVE SUBSTANTIAL REDUCTIONS. WE ARE DISCUSSING A VERY COSTLY PROGRAM. $30 TO $40 BILLION WORTH OF INVESTMENT IN CAPITAL ALONE. IF WE DO NOT APPLY CONTROL REQUIREMENTS CAREFULLY OR ALLOW SOME MARKET MECHANISM TO OPERATE, WE WILL EITHER SPEND SUBSTANTIALLY MORE THAN IS NECESSARY TO ACHIEVE OUR GOAL OR GET MUCH LESS BENEFIT THAN WE SHOULD FOR THE DOLLARS WE INVEST. I DON'T KNOW THAT THE PROPOSAL IN MY BILL -- AN INSTRUCTION TO EPA TO PREPARE A PRIORITY LIST OF INVESTMENTS USING AN REDUCTIONS MAXIMIZATION RULE TO SET PRIORITIES -- IS THE BEST WAY TO GO. BUT I MUST SAY TO THE COMMITTEE, THAT I DO NOT HAVE CONFIDENCE IN THE APPROACH REFLECTED IN THE BILL REPORTED LAST YEAR. IT ALLOCATES REDUCTIONS TO STATES BY A SOMEWHAT ARBITRARY FORMULA AND THEN REQUIRES STATES TO DETERMINE WHERE THAT ALLOCATION WILL BECOME A SPECIFIC CONTROL INVESTMENT. UNLESS IT CAN BE DEMONSTRATED THAT THIS APPROACH WILL BE COST EFFECTIVE, I THINK THAT WE NEED TO CONSIDER OTHER ALTERNATIVES.

A FIFTH AND FINAL QUESTION IS WHETHER WE HAVE THE INSTITUTIONAL ability to develop a control program at all. Bill Ruckelshaus describes the acid rain problem as the most intractable political issue he has ever experieinced. Having the potential to set one region of the nation against another.

I think it essential that this committee consider this fifth question along with all the others as it develops an acid rain bill. From what I have seen over the last few months, getting a solution to the acid rain problem depends on the senators gathered in this room. We need to develop some momentum on this question. We need to convince the Senate, the House, the Administration and the nation that acid rain legislation is a certainty in this Congress.

Mr. Chairman, when we return for the second session, I hope you will put us on a forced march until an acid rain bill is signed by the President. I am willing to commit some portion of everyday to that effort, if I can be of assistance. But let's make it clear to everyone now that we are determined to produce legislation at the earliest possible date.

Thank you, Mr. Chairman.

Senator Stafford. Prior commitments have prevented Senator Simpson from attending today's hearing: he has submitted a statement which will be entered at this point in the record.

[Senator Simpson's statement follows:]

STATEMENT OF SENATOR ALAN K. SIMPSON

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

NOVEMBER 2, 1983

MR. CHAIRMAN, WE ARE HERE TO ONCE MORE ATTEMPT TO OBTAIN A SENSIBLE VIEW OF THE ACID RAIN QUESTION. THERE HAS BEEN A PLETHORA OF INFORMATION PUBLISHED AND DISTRIBUTED IN REGARD TO THE DOCUMENTED AND UNDOCUMENTED EFFECTS OF ACID PRECIPITATION AND THERE HAS BEEN CERTAIN NEW INFORMATION COME TO LIGHT SINCE WE MET LAST TO REVIEW THIS ISSUE. THERE HAS ALSO CONTINUED A DEBATE WITHIN THE SCIENTIFIC COMMUNITY THAT IS STUDDED WITH PHRASES LIKE "SOURCE RECEPTOR RELATIONSHIP" AND " PODILIZED ACID SOILS" AND OTHER CHOICE PHRASES FROM THE SCIENTIFIC LEXICON. HOWEVER, EVEN AFTER REVIEWING THE LATEST INFORMATION I HAVE FOUND THAT THE BOTTOM LINE HAS NOT CHANGED SIGNIFICANTLY -- AND THAT IS: THERE PERSISTS A SIGNIFICANT DEGREE OF SCIENTIFIC DISAGREEMENT AMONG THOSE STUDYING THE ACID RAIN PHENOMENON. I AM AWARE THAT RESEARCH IS ONGOING AND THAT IT MAY BE SEVERAL YEARS BEFORE THE FINAL RESULTS WILL BE IN. I DO NOT MEAN IN ANY WAY TO DETRACT FROM THESE HEARINGS -- IN FACT, I AM CERTAIN WE WILL FIND THEM TO BE MOST USEFUL IN HELPING TO REFINE THE

INFORMATION THAT HAS ALREADY BEEN MADE AVAILABLE TO CONGRESS. YET, IT IS READILY APPARENT THAT CONGRESS INTENDS TO DEAL WITH THIS ISSUE IN THE NEAR FUTURE -- BEFORE ALL STUDIES ARE COMPLETED. THIS IS THE REASON THAT THE COMMITTEE BILL WAS CONSTRUCTED IN THE FASHION THAT IT WAS LAST YEAR -- IN ORDER TO ALLOW FOR A VARIANCE IN COURSE ONCE ALL OF THE INFORMATION IS IN. IN ADDITION, THE COMMITTEE CHOSE THEIR APPROACH LAST YEAR IN A WAY THAT WOULD ADDRESS THE PROBLEM WHERE IT OCCURS -- IN THE 31 STATE ACID RAIN REGION -- WHERE ACIDIC SOILS DO OCCUR FREQUENTLY AND WHERE ACIDIFICATION IS A DOCUMENTED AND CONTINUING OCCURENCE. SIMILARLY, THE COMMITTEE CHOSE THE APPROACH WHEREBY THOSE 31 STATES WOULD BE PRIMARILY RESPONSIBLE FOR THE REDUCING OF EMISSIONS IN THE REGION -- AND I BELIEVE THAT IS SO IMPORTANT. IT EMBRACES THE CONCEPT WHERE THOSE STATES THAT HAVE CONSCIOUSLY CHOSEN NOT TO REQUIRE STRINGENT AIR QUALITY STANDARDS -- THOSE STATES THAT HAVE CHOSEN TO DEFER THE HARD DECISIONS THAT ARE NECESSARY TO CLEAN UP SULFUR EMISSIONS WILL BE THE STATES THAT SHOULD BEAR THE BRUNT OF RESPONSIBILITY FOR "CLEANING UP THEIR OWN ACT."

ACID RAIN IS NOT RECOGNIZED AS A WIDESPREAD PROBLEM IN THE WEST. IN FACT ONLY A FEW "HOT SPOTS" EXIST WHERE ACID PRECIPITATION IS CAUSING LIMITED ENVIRONMENTAL DAMAGE. THE WEST HAS TRADITIONALLY HAD LOWER SULFUR EMISSIONS THAN THE EASTERN STATES AND THAT TREND WILL ASSUREDLY CONTINUE INTO THE NEXT DECADE. HOWEVER, WE MUST BE VIGILANT IN GATHERING BASE LINE DATA IN AREAS WHERE HIGH MOUNTAIN LAKES OCCUR IN GRANITE GEOLOGIC STRUCTURES WITH POOR BUFFERING CAPACITY. WE SHOULD BE WARY OF OVER REACTING TO THE ACID RAIN SITUATION BY REQUIRING THAT ALL 50 STATES IMPLEMENT MASSIVE SULFUR REDUCTIONS. LARGE SULFUR REDUCTIONS ARE ALREADY IN PLACE IN THE WEST -- WHERE MY STATE OF WYOMING HAS THE MOST STRINGENT STANDARD OF ALL AT .2 LBS.

I DO NOT THINK THAT THERE IS A MEMBER OF THIS COMMITTEE THAT ISN'T SENSITIVE TO THE POSSIBLE CONSEQUENCES THAT AN ACID RAIN CONTROL BILL WILL PRODUCE IN THE MIDWESTERN STATES. THE COMMITTEE DID CERTAINLY TAKE THIS INTO ACCOUNT LAST YEAR, AS IT WELL SHOULD THIS YEAR. THAT IS WHY THE INDIVIDUAL STATES ARE GIVEN THE OPPORTUNITY TO CHOOSE BETWEEN A RANGE OF CONTROL MEASURES IN ORDER

TO MEET THE FINANCIAL NEEDS AND CONDITIONS OF EACH STATE. I AM VERY GRATIFIED THAT SENATOR DURENBERGER HAS JOINED THE COMMITTEE ALONG WITH SENATOR HUMPHREY -- SO THAT WE MAY HAVE FRESH INSIGHTS ON THE PERCEPTIONS AND NEEDS OF MIDWESTERN AND NORTHEASTERN STATES. I LOOK FORWARD TO WORKING WITH THESE FINE NEW COMMITTEE MEMBERS AS WE AGAIN TAKE A CLOSE LOOK AT THE ACID RAIN ISSUE. I TRUST THAT THE COMMITTEE MAY AGAIN LOOK AT THE ACID RAIN ISSUE. I TRUST THAT THE COMMITTEE MAY AGAIN FORMULATE A MODERATE AND SENSIBLE ACID RAIN CONTROL MEASURE THAT BALANCES CAPITAL REQUIREMENTS WITH ENVIROMENTAL NEEDS. THIS HEARING WILL UNDOUBTEDLY ASSIST US IN DEALING WITH THESE ISSUES SPECIFIC TO THE NORTHEAST.

Senator STAFFORD. All right. For the committee we are very happy, Senator Byrd, to welcome you here as the distinguished minority leader of the Senate, and we would welcome your testimony at this point.

STATEMENT OF HON. ROBERT C. BYRD, U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator BYRD. Thank you, Mr. Chairman, and I thank all of the members of the committee.

Let me begin by commending you for holding these hearings. I appreciated your nice letter to me of recent date in which you invited me to appear.

After struggling with this issue for about 2 years now, I think that the one thing we can agree on is that this is one of the most complex and divisive policy issues of the 1980's.

I understand that these hearings are being held to provide the committee with updated scientific information with respect to acid rain. I am glad to hear that because it has seemed to me that since the issuance of the National Academy of Sciences' report on acid deposition it has become clear that the scientific debate over acid rain is not over, as some would have us believe.

Indeed, the report was an extremely cautious document which did not address a number of important questions. For example, the report did not address the incidence or extent of environmental or health effects. The report did not directly address the policy question of whether an acid rain control strategy which emphasizes disproportionate sulfur dioxide reduction from the Midwest and Appalachia would be effective in protecting sensitive areas of the Northeastern United States.

Despite these limitations, the NAS report is an important document and a useful one for it does appear to define some of the major areas of scientific uncertainty with respect to the causes of acid deposition.

I found some of the conclusioins of the report to support my position on this issue. For example, the report concluded that:

> All sources of SO_2 and nitrogen oxide in Eastern North America must be considered as contributing in one degree or another to the phenomenon of acid deposition. Evidence exists for long-range transport of pollutants leading to acid deposition, but the relative contributions of specific source regions to specific receptor sites currently remain unknown.

I am not a scientist, I am sure I do not need to say, but it seems to me that one implication of that statement is that the scientific community does not know whether an acid rain control strategy which requires coal-fired powerplants in the Midwest and Appalachia to significantly reduce emission of SO_2 will be effective in protecting sensitive areas of the Northeast.

The NAS report further states that air-quality computer models:

> Have not provided results that enable us to have confidence in their ability to translate SO_2 emissions from specific sources to the degree of acid precipitation in specific receptor states or regions.

Once again, it seems to me that the Academy report is saying that the scientific community does not have the research tools available to determine the consequences of "alternate control strategies" which purport to address the long-range transport and deposition of acidic material. Yet, it seems to this Senator and to many of our colleagues that we should make every effort to make ourselves fully aware of the consequences of acid rain control strategies.

The Academy also concluded that:

> The relative importance for deposition at specific sites of long-range transport from distant sources as compared with more direct influences of local sources cannot be determined from currently available data or reliably estimated using currently available models.

It does not seem to me that this conclusion would provide support for an acid rain control strategy which requires disproportionate emissions reductions from the Midwest and Appalachia.

Finally, Mr. Chairman, the Academy came to a curious conclusion with respect to the issue of "linearity," one of the key theoretical premises of this entire debate. The Academy's report concluded that:

> There is no evidence for strong nonlinearity in the relationships between long-term average emissions and deposition.

So, it seems to me that one of the key issues of the debate, the Academy "blinked." They did not say that the relationship is linear. Instead, they issued a statement with a double negative.

I hope that the scientists who will be appearing before this committee will be able to clarify this statement and shed some light on the reasons for such a convoluted conclusion. This is an important issue to all of us, and I am sure that the committee is aware that the Academy's conclusion is not the equivalent of a proof of linearity.

Mr. Chairman, you and the members of the committee are aware of my position on the issue of acid precipitation. My bill, the Acidic Deposition Mitigation and Research Act of 1983—S. 454—calls for an acceleration of the scientific work of the Interagency Task Force on Acid Precipitation, and provides for measures to alleviate the effects of acid deposition on sensitive areas. Based on the NAS report and other information, I think that this is a prudent and reasonable course.

But let me say that my position, a position which is shared by a number of my colleagues, recognizes the concerns of Senators who feel that we must act now because the sensitive areas of their States are at risk. My concern, and the concern of the cosponsors of S. 454, is that the acid rain control proposals which have been unveiled thus far are very expensive and will place thousands of jobs and hundreds of communities in our States at risk.

If powerplants in our States are required to install scrubbers, the capital and operating costs would be very high. This would cause utility rate increases for the residents of our State and other States. In West Virginia, it is estimated that capital costs for retrofitting scrubbers would range from $640 million to $1 billion, depending on the level of scrubbing required. Annualized costs would be from $205 million to $333 million. In some States it is estimated that utility rate increases could be between 14 and 20 percent. The cost of a massive control program could be from $20 billion to $40 billion over the life of the program.

In comparison, less expensive and direct approaches can be designed, such as liming of lakes. The cost of such a program has been estimated at about $20 million. Its effects would more immediately be apparent. It would address directly the problem of lake acidification.

On the other hand, if utilities are allowed to pursue the so-called least cost strategy, switching to low-sulfur coal, this would result in severe disruptions in the traditional coal markets, especially in the high-sulfur coal producing areas of the Midwest and Northern Appalachia. High unemployment and severe dislocations in hundreds of coal-mining communities in these areas would be the result.

For example, there are estimates that the Midwest would experience a decrease in coal-mining employment in 1995 of 12,300 jobs from the 1980 level. That is the estimate made by ICF, Inc. That is a respected energy consulting firm.

An analysis of the impacts of acid rain control strategies by the Congressional Research Service indicates that my State of West Virginia could experience employment losses of as much as 24,500 in 8 northern West Virginia counties. Those are the counties of Barbour, Upshur, Marshall, Randolph, Marion, Monongalia, Harrison, and Preston.

By the way, those 8 counties produce 80 percent of the coal that is produced in the northern part of West Virginia.

It seems to me that acid rain control proposals put us in a cruel dilemma. If we are required to use scrubbers, the costs will be high and utility bills will soar. If the guiding principle is "least cost"—in other words, switching to low-sulfur coal—we face the prospect of disruptions in high-sulfur coal markets, high unemployment in the coal industry, and economic dislocations in coal-mining communities. In West Virginia, a State that already leads the Nation in unemployment.

I think we need to address the scientific challenges raised by the acid rain debate. But we also need to address the technological challenges raised by this debate. We urgently need an accelerated program of coal R&D—coal research and development—to develop in a timely manner a variety of advanced coal technologies representing more efficient and economically attractive alternatives to current coal technologies.

Unfortunately, we—and when I say "we" I include the executive branch—have not acted with sufficient conviction in the past to develop that variety of technological options which would enable us to use coal in an environmentally and economically acceptable manner. Improvements have been made in combustion efficiency, but the range of options for controlling or eliminating emissions from coal combustion remains expensive, unreliable, and very limited.

That is why I introduced the National Coal Science, Technology, and Engineering Development Act—S. 1925. My bill calls for a 5-year accelerated program to bring specifically designated technologies to the point of commercial application. While I am here, I take this opportunity to urge my colleagues on the committee to join as cosponsors of that legislation.

In closing, Mr. Chairman, let me say that we should not be pursuing policies which will render large segments of the Nation's vast coal reserves unmarketable. We should be pursuing policies which will enable us to maximize the potential of our coal reserves while meeting the Nation's environmental goals.

We should not be pursuing policies which would impose further economic hardship upon the economies of States like West Virginia, Ohio, Pennsylvania, Illinois, Indiana, and Kentucky. We have the time to act with due deliberation and caution. We must seek to be fair and equitable in our evaluation and distribution of the costs and the benefits. We must insure the judicious application of scientific knowledge, balanced against the costs and benefits in the development of any approach to the problem of acid rain.

Mr. Chairman, I have some materials here I would ask unanimous consent to have appear in the hearing record.

Senator STAFFORD. Without objection, they will be.

Senator BYRD. Mr. Chairman, that concludes my prepared statement.

Senator STAFFORD. Thank you very much, Senator Byrd. We appreciate, as I said, your coming here and counseling with our committee.

I have no questions. Senator Randolph, do you?

Senator RANDOLPH. Yes; very briefly. Knowing of Senator Byrd's commitment, if agreeable to him, I will have certain questions and they could be submitted and responses might be made later. That might accommodate your schedule.

Senator BYRD. I appreciate my senior colleague's desire to accommodate me. But I have blocked out a window in my time this morning. So, if the Senator wishes to ask me the questions, I will be glad to attempt to answer.

Senator RANDOLPH. Thank you.

In the statement by the minority leader I think that generally it is well reasoned in its content and he has at least in part described the legislation which he has introduced.

I think for the record I would like to say that you have 15 cosponsors besides yourself on the legislation. I believe that is correct. So, there are 16 Members of the Senate that are joined, with Senator Byrd as the principal sponsor.

At this point, only for the record, the measure that I have introduced, which is Senate 766, is somewhat similar to Senator Byrd's measure but differing in certain parts. I am joined by Senator Specter of Pennsylvania in the presentation of that legislation. I think we are both discussing in our two measures accelerated research and a program, certainly, for mitigating the effects of acid deposition on the waters and soil. That might be approached differently, but it is there.

In addition, the legislation that I have sponsored, I think it is appropriate to just mention it in the content here of the testimony of our able Leader, it would limit emissions and establish what I call a cap on sulfur dioxide emissions.

Now, in the testimony, Senator Byrd, that you have given, you recognize that certainly acid rain is a concern to the Members of the Senate and the House and you think in terms of the problems of the Northeast. Those are the problems which have been often brought to our attention by Senator Stafford, our chairman, and by the Senator from Maine, Mr. Mitchell.

You have stressed the economies of the Midwest and especially of Appalachia. You have indicated that they would be severely impacted if a stringent acid rain measure was passed. You do think in terms of coal as continuing to meet the Nation's energy needs. I know of your contribution on many occasions, indicating that we have spent excessive, amounts of money on nuclear research but very little on coal research.

Would you comment on that latter statement of mine?

Senator BYRD. Yes, Mr. Chairman.

This administration has probably put coal research on the lower end of the totem pole. I might cite one specific instance in which SRC-II, which would have been located at Morgantown, W. Va., and which would have provided a low-sulfur content liquid boiler fuel—I should say with reference to that SRC-II project, the Germans had committed themselves to pick up 25 percent of the cost, the Japanese 25 percent of the cost, and Gulf Oil $100 million.

This administration recommended—or I suppose I should say—ordered its representatives to those talks to terminate the talks. I talked to the President about this and he said it was his belief, and I have no doubt that he is very sincere in his belief, that the Federal Government should not be doing this, that private industry ought to be doing it.

Whereupon I cited him the fact that I had had the vice president of Gulf Oil and the chairman of the board in my office and had asked whether or not they could increase their contribution of $100 million. They responded to the effect that that was the absolute cap on their contribution, that they had a great deal of difficulty in convincing their board that it should even go as far as $100 million.

Well, $100 million represented 5 percent of the overall estimated cost of that project. So, I must say with all due deference to the administration that it has not looked upon coal research and projects that would produce synthetic fuels from coal very favorably—and that is putting it in the best context that I can put it.

I think we should press harder for the development of synthetic fuels from coal. We put into place a national energy policy—whatever may be said about President Carter and I found a few occasions on which I openly disagreed with him and did not hesitate to say so, at least he sent up to the Congress a national energy policy proposal.

During that period, we put into place a synthetic fuels program which under this administration has been pretty much emasculated. I do not believe that the private sector is prepared to pick up these high-risk ventures that will cost lots of money. But we are going to look around 1 day, 10 or 15 years from now, and wonder, where the the synthetic fuels when we will again see the long gas lines at the gas stations. I would hope that never happens but I fear that it could, for various reasons.

Senator RANDOLPH. Mr. Chairman, I hesitate saying what I am now but I think it naturally follows what Senator Byrd has said.

I must remind you that we go back to 1944 for the first synthetic liquid fuels legislation which became law. It was signed by Franklin Roosevelt into law. I had the opportunity of cosponsoring the measure with the Senator from Wyoming at that time.

Now on this Sunday, November 6, we will be in Morgantown and it was 40 years ago on November 6 that we made the flight from Morgantown to Washington in a single-engine aircraft that was fueled with processed gasoline made from West Virginia coal. So, we have known that we can do this over a long period of time and it is regret-table, as Senator Byrd has indicated, that there has not been a continuity of programing.

We had $75 million to begin with which was to prove that we could do the job, and we proved it. Not only on coal but on shale and forestry, and agricultural products. I will not go into the politics of the matter.

But, Mr. Chairman, $3 million was returned to the Federal Treasury and the whole program was closed down—and not under Franklin Roosevelt, I will say. I will not get into politics on it. I sometimes look back on these matters and worry about what we have failed to do.

I think that it is perhaps appropriate to say that the Governor of our State has indicated his preference that no acid rain control legislation be enacted at too soon a date. I want to be careful about that. He has stated his position on several key issues if a control program were to be considered. He says he would insist on technological controls to avoid fuel switching and protect our high-sulfur coal, and to seek a national participation in the cost of the controlled program.

I think that Senator Byrd in essence has said something of this kind. If an acid rain control program were enacted, would Governor Rockefeller's suggestions make sense to you, Senator Byrd, if such a program came into being?

I do think that technological controls are highly important, I say that for myself.

Senator **Byrd**. For the purpose of these hearings, Senator Randolph, I think we ought to make haste slowly and make sure that we are right before we impose upon the country costly programs which would require industries to install equipment which might later prove to be ineffective once more is known about acid precipitation, its origins, its causes and its effects, and which would throw thousands of coal miners out of work and which would also, if we used a multiplier factor of 2.25, throw a lot of other people out of work—the butchers, the welders, the gas station attendants, I mention those three because I have done all of them; the produce salesmen, the baker and the candlestick maker, and which would cause some industries to close down.

Not only coal mines in northern West Virgina in the eight countries that I have referred to but other industries as well. I was talking with one of the top people of Kaiser Aluminum, which has a plant in West Virginia, recently, and said, "What will happen to your plant if this acid rain legislation goes into effect?"

He said, "We will probably have to close down because of the increased energy bills."

So, I think we ought to try to resolve this problem. I think my bill would do that. We can do that by pushing the interagency study, its final report from 1982 forward to 1987, and in the meantime do what we can do to mitigate the effects of acid precipitation, whether it is wet or dry, and whether it comes from distant sources or in considerable measure from local sources. We ought to do what we can to alleviate those conditions.

In the meantime, proceed with the accumulation of scientific data which would give us the proper guidelines under which we would approach this very serious problem.

Senator **Randolph**. This final comment, Mr. Chairman, and I appreciate your permitting me this time.

The coal industry, as Senator Byrd knows, has recently indicated that coal utilization, particularly in the eastern market, may actually shrink in the 1990's. This might be helpful in reducing deposition without the need for additional regulation. It would be disastrous, very frankly, as Senator Byrd has said, for the coal miners by the tens of thousands.

I think, Mr. Chairman, although there is a difference within our committee on this matter and in the Congress, I think we should be especially careful about imposing a control program—and I say this to Senator Mitchell—which could be very disruptive beyond what really we are saying here today.

I know that Senator Byrd has given his thoughts on this subject and perhaps other members of the committee may give their thoughts this morning.

I commend my colleague, it was very helpful to have his statement made after very well reasoned judgments.

Senator **Stafford**. Thank you very much, Senator Randolph.

Senator Chafee, do you have any questions?

Senator **Chafee**. No; I do not, Mr. Chairman. I was very interested in the testimony of Senator Byrd who obviously is knowledgeable and concerned about this area. I found it very helpful and fruitful.

So, I appreciate your taking the trouble to come, Senator.

Senator **Byrd**. Thank you.

Senator **Stafford**. Thank you, Senator. Senator Mitchell?

Senator **Mitchell**. Thank you, Mr. Chairman.

I have no questions, I would like to make just a couple of brief comments and ask to have some material placed in the record.

I do join with Senator Chafee and the chairman in thanking Senator Byrd for his testimony. We certainly will review it with great care.

As the Senator is, I am sure, aware the conclusions which he has reached in the matter are the subject of some considerable dispute and there is evidence to the contrary, dealt with two subjects primarily, first is employment in the coal industry.

Mr. Chairman, I have read two studies, one by the U.S. Office of Technology Assessment, the other by the consulting firm of ICF, Inc., done for the Alliance for Clean Energy, both of which reach the conclusion that national coal production will increase significantly by the 1990's and that increase will be unaffected by enactment of legislation controlling acid rain.

I should note that the Office of Technology Assessment study does indicate that there will be some regional redistribution of employment. Interestingly enough, the conclusion is that West Virginia will be a net gainer in that effort. According to these studies, West Virginia will experience a net increase in employment in the coal industry if the legislation I proposed is enacted.

I also have, Mr. Chairman, a study on Comparative Electricity Rates, done by the consulting firm of ICF, Inc. That study indicates, first, that electricity rates in the midwestern and midatlantic region are substantially lower than those in the northeastern region of the country now, and that even were legislation of this type enacted, those rates would remain very substantially lower than rates are in the East and the Northeast States for the reasons I suggested earlier.

While of course I conclude by saying to my good friend, Senator Randolph, as I know he understands, I have no desire in pursuing this legislation to be disruptive in any respect of the people of West Virginia. I am sure he appreciates that we in other parts of the country do regard it as calling for some action when we see the destruction of our water resources.

It is my hope, as he said so eloquently in his opening remarks, that we do not end up with State against State, region against region, but recognize that we are all Americans and that the resources that happen to be located within the artificial boundaries of one State—whether they be coal resources in the Midwest or water resources in New England—are in fact the resources of all Americans and that we must do what we can to preserve, protect, and develop them in a fair and equitable manner.

Senator **Stafford**. Thank you very much.

Senator **Byrd**. Mr. Chairman, may I just comment on what my good friend, Senator Mitchell, has referred to as an increase in jobs if this legislation is enacted, in West Virginia.

Senator **Stafford**. Certainly.

Senator **Byrd**. I would hasten to say that I recognize that there is a problem in the Northeast and in the Senator's State, in Maine, and I respect him for his viewpoint.

But I would hope that the committee would not be persuaded to believe that there would be an increase, an overall increase, in jobs in West Virginia. I will use my own State as an example.

I have heard the same thing said by other people. But the truth of the matter is, Mr. Chairman, that if we are going to force those powerplants—and there are 5 in West Virginia that would have to either install scrubbers or go to low-sulfur coal, and those 5 generate about 57 percent of the electricity that is generated in West Virginia—if they should have to do that, it would be a tremendous cost insofar as scrubbers are concerned, as I have already indicated.

But as to jobs, the theory is that they can switch to low-sulfur coal, therefore creating additional jobs in southern West Virginia where we have some of the finest low-sulfur coal in the world, while we lose jobs in northern West Virginia.

Now, can you imagine the destructiveness to the communities in northern West Virginia which would be adversely affected if this so-called lowest-cost approach were to be taken? Those additional jobs in southern West Virginia would be absorbed by miners who are out of work there, already out of work, metallurgical coal-producing mines and in steam coal-producing mines.

There are thousands of unemployed coal miners in southern West Virginia. When you look at the southeastern counties of West Virginia, great coal-producing counties, you find as high as 60 percent of the miners unemployed. In Gary, W. Va., 90 percent of the coal miners are unemployed.

So, if the powerplants switched to low-sulfur coal as the answer, there is still going to be an increase in the utility bills. Also, there is no guarantee whatsoever that such increase in the use of low-sulfur coal, Senator Mitchell, would take care—if I may use that poorly chosen couple of words—of those unemployed in northern West Virginia, the unemployment in northern West Virginia, that would result from passage of the legislation that has been passed out of this committee.

That additional employment in low-sulfur areas would quickly be absorbed by the miners in those areas who are already unemployed.

Also, when we talk about creating more jobs in southern West Virginia and the people from northern West Virginia can move down there, we are kidding ourselves. The loss of jobs will not be confined just to the coal mines, but whole communities will be devastated. I mentioned the 2.25 multiplier effect a while ago. For every job that is lost in coal mines in northern West Virginia, there will be two-and-a-quarter jobs lost in other associated professions or whatever one may wish to call them—I am talking about the butcher, and the baker, and the banker, and the insurance salesman, and the automobile repairman, and the car dealers, and on, and on, and on.

So, let it not be said, let this not go unchallenged, that there will be an increase in the number of jobs because, as I have said, Senator Mitchell, those coal miners in the northern part of West Virginia are not going to get those jobs in southern West Virginia. Those people who are already there are going to get them, first of all.

If there should be an increase of coal mining in the West, I cannot picture coal miners being uprooted from their homes, from the communities in which they and their fathers, and grandfathers, have lived. I cannot see them going to the West.

Besides, when it comes to retraining of coal miners, that is a costly procedure and there is no assurance that once the coal miner is retrained, that the job will be available for him for which he was retrained. We have coal miners whose work in the mines, as I say, has gone from generation, to generation, to generation.

As one who grew up in a coal mining community and in a coal miner's home, I think I know a little something about the impact on the coal mine industry in West Virginia and I am prepared to take that case to the floor and discuss it at great length.

Again, I respect the Senator from Maine, he is one of our, I would say, brightest and most effective Senators. He is reasonable. He is a former judge, he is judicious, and I have great admiration for him. I believe in George Mitchell.

He is to be respected for trying to do something about the problem that affects his State, I do not blame him for that. If I lived in Maine, I probably would be taking the same position.

I want to see this problem dealt with. But I think what I am trying to say is, the bottom line is that we just do not have the scientific information that is agreed upon, not disputed, that represents a consensus amongst the scientists as to what are the causes, the origins, and the effects of acid precipitation.

While I certainly have every respect for George Mitchell and his dedication to serving his State, I recognize his problem. I want to help to do something about it. But I just do not believe that we have the scientific data that is necessary to justify the kind of approach that is being suggested—I say this with high respect and kindness to my good friend.

But I am prepared and will be prepared to discuss this in depth when it reaches the Senate floor. I am sure that Senator Mitchell will be ready, also, to discuss this. This is a complex problem and, as I say, we ought to make haste slowly. We ought to look before we leap, and in the meantime we can do some things that will alleviate the problems to which Senator Mitchell has addressed his remarks and to which other Senators on this committee would address theirs.

Senator **Mitchell**. Well, I thank you, Senator. I similarly respect your commitment on behalf of the people of your State, and acting in a manner which you believe to be in their interest.

You have responded to several assertions which I did not raise. I asked that studies be placed in the record which reached a conclusion different than yours. I recognize, as you do, that there are different points of view.

I will say in response to your remarks that it is a peculiar problem of controlling pollution in a modern, industrialized society. That it is far easier to specifically assess the costs of action and far more difficult to assess the costs of inaction.

By their very nature clean air, pure water, unpoisoned land, are difficult to attribute specific dollar values to. Nonetheless, in clear and unmistakable terms the people of our Nation have stated over and over again their desire for that quality of environment.

That is not to say that the current and ongoing costs of acid deposition are without some estimates. I point out to the Senator that one scientist has estimated that the current cost of damage from acid deposition in the United States approximates $5 billion a year. So, there are costs being assessed at this very moment by our failure to act on the problem.

Second, while I know that the Senator's arguments are sincere, deeply held, and indeed very forceful, I would point out that precisely those arguments—scientific uncertainty, high social cost, structured unemployment—have been made in opposition to every piece of major environmental legislation that has ever been proposed in this Congress and in this country.

Each time the Congress has seen fit to take appropriate action, and in each case and continuing to this very moment, people of this country have reaffirmed their overwhelming support for that legislation.

The Clean Air Act costs the American people a lot of money and they know it. And they pay it, and they support it.

The Clean Water Act costs the American people a lot of money. And they know it, and they pay it, and they support it because they recognize that the benefits to be derived in terms of a higher quality environment, the essentials of life—clean air, pure water, unpoisoned land make it appropriate to do so.

I know the Senator shares those views. I know he wants to work something out, and I want to say that I look forward, in the course of these anticipated lengthy discussions on the Senate floor to which the Senator has alluded, to discussing this and hopefully arriving at some mutually acceptable conclusion that will be in the interest of the people of this country.

Senator **Byrd**. Mr. Chairman, if I may comment further.

Senator Mitchell and I are not going to settle the scientific questions here today, and primarily this hearing is for the purpose of listening to scientists.

But I do want to say a couple of things in response to what Senator Mitchell has just said. We have heard of the Clean Air Act and the Clean Water Act and he said the people of this country wanted it. I voted for both of them. I was here when they were being debated and I supported them.

He also says—and I do not question this—that it is difficult to assess the costs of damage to the land, to the soil, to the water, forests, created by acid deposition, whether it be dry or wet.

I do not question that. But what the point I am making is, it is also, apparently, difficult to determine what is causing that damage and what the sources are for the acid precipitation. You have, I believe, an estimated 2,760 lakes in the Adirondacks, and about 206 of those have been affected by acid precipitation. This represents about 4 percent of the surface area of the total number of lakes there.

What I am saying to my good friend is, there are damages. It is difficult to assess the costs of those damages. But I would simply hope that we would not rush to the conclusion that the bill the committee, has under consideration is going to undo the damages. That is what I am saying; let us find out what the causes are and address those causes.

I do not question the damages. What I do question is the approach that is being hurriedly proposed here, dealing with the origin and causes of the damages when we do not know—we do not know—that that approach would be successful or effective.

Mr. Chairman, I am going to let the Senator have the last word here if he wishes to say any more because this committee is not here today to listen just to me and I think it should soon turn to the scientists who know more about it than I do, and they cannot even agree.

Senator MITCHELL. I would say, the Senator is entitled to the last word and has just had it.

Senator STAFFORD. Well, that depends on whether other members of the committee have any word here. Senator Durenberger?

Senator DURENBERGER. I will pass on it.

Senator STAFFORD. Senator Baucus?

Senator BAUCUS. Thank you, Mr. Chairman.

Senator, I appreciate the point of view you have taken here; that is, protecting your State of West Virginia and also how you see we should approach the problem, and that is to go slow.

I also very much appreciate the point of the Senator from Maine, that his State is more directly affected by this problem than most other States in the Union.

As we look for a national consensus, though, let me point out the problem from my State's point of view. Our State, the State of Montana, and other Western States generally, are spending a lot of money to build and to put in place very high technology to reduce sulfur dioxide and other emissions.

For example, coal strip 3 and 4, each producing and will produce when on line about 750 megawatts of power cost about $1.4 billion total. When those plants are complete, those powerplants will emit 0.07 pounds of sulfur dioxide per million Btu. That, as you know, is very much lower than the average sulfur dioxide emissions of most of the other powerplants which range in the neighborhood of approximately 5 or 6 pounds per million Btu to as low as 1 pound.

The Montana powerplants, as I said, cost $1.4 billion to build them, and about $500 million of that is spent on technology needed to reduce emissions, it will be about 0.07 pounds per million Btu.

So, in any attempt to find a solution here, that is in any attempt to assess the damage on the one hand, then determine how we pay for solving the problem on the other, we in the West feel that we are paying more than our fair share to cleanup the environment as we are spending the money that is necessary to make sure that sulfur dioxide emissions are as low as they possibly can be.

Back to coal strip 3 and 4, Senator, they meet the class I standards. That is one of the first times that will occur in our country, the emissions are so low.

So, we in the West are very much opposed to any national tax, any approach—assuming there is a movement here—where we would have to pay an additional tax—we already are paying our fair share—so that other plants in other parts of the country, in other States can either install scrubbers or maybe move to low sulfur coal, or whatever.

But I am wondering, Senator, if you could address yourself to our concern, that is whether your approach would take account of that. Mostly, I am pointing out, that we in the West have a very strong point of view on this problem, too. Yes; we should try to stamp out the problem. Yes; we should do it judiciously and fairly. But in any attempt to do so we, in the West, do not feel that it is proper to pay an additional cleanup charge when we are already paying our fair share, and that those funds will then go to other parts of the country.

Senator **Byrd**. Unless I can be better persuaded than I am at the moment, I do not like the idea of a national fee. I am not saying I cannot be convinced that it is in our interest, and I would like to listen to the debate on that.

Secretary of the Treasury Regan is very much opposed to the fee.

I think we are all paying in the case of higher utility bills. I just happened, as some would say, to bring along a couple of the utility bills that I have paid.

I sometimes, Senator Bentsen, jokingly say that my occupation is "slave" and that I am working for the Internal Revenue Service and VEPCO.

I said to my wife this morning, "How much have we paid in utility bills this year, this far?" She said, "$2,477." And she reminded me that that was in the face of a rather mild winter.

The bill for March, $499.25. The bill for February, $422.74, and in some instances over $500 a month.

Now, I am one of those Senators who happens to believe that he is worth what he is paid, and I think most Senators probably are in my same position. But that is an extraordinary heat bill. What are the old folks going to do who live on a very limited income when their utility bills are forced higher and higher?

There is no question but that this legislation is going to result in that. And if we talk about a national fee, how are they going to pay that? Because all of these bills are going to be passed on to the consuming public. How are they going to pay for this, the old folks, the veterans who are living on a limited pension?

So. I agree with you certainly at this moment that a national fee is not the answer. I simply say we ought to go slow. And by slow I do not mean postpone it forever, but we certainly ought to not be hasty in rushing toward what we think is a solution when the scientists cannot agree on it and when the data is not sufficient.

I commend the Senator for his diligence in looking after the interests of his State and his people. He is very diligent about that.

Senator Baucus. Thank you very much.

Senator Stafford. Senator Bentsen, do you have any questions?

Senator Bentsen. I have no questions.

Senator Stafford. If there are no further questions, I think the chairman is going to have the last word here. That is simply to say that as was once said politically, "As Maine goes in this particular issue, so goes Vermont."

Senator Bentsen?

Senator Bentsen. I apologize for not being here earlier to hear this very important debate and presentation, but I was chairing a subcommittee—and Democrats get to do this so seldom these days that I could not pass it up.

Senator Stafford. Thank you, Senator Bentsen.

Senator Byrd, we really do appreciate your coming here. We know it has taken a lot of your time to prepare and to be here, and you helped this committee.

Senator Byrd. Well, you have been very generous in your time with me and most kind. The debt is from me to you, not from you to me. Thank you very much.

Senator Stafford. Thank you, sir.

Senator Durenberger. Mr. Chairman, I do have an opening statement that I deferred until the conclusion of Senator Byrd's statement.

Senator Stafford. The Chair understood that, and at this point the Chair would be pleased to have your opening statement made.

Senator Durenberger. I hesitate to do this.

Senator Stafford. Without objection, we will place it right after the statements of Senator Randolph and myself.

Senator Durenberger. Thank you very much, Mr. Chairman.

I enjoyed the debate and the discussion that followed the minority leader's testimony. But just to preface my remarks, he quotes the high capital cost for retrofitting, the annualized cost of retrofitting and the 14- of 20-percent utility rate increase in West Virginia, our distinguished minority leader goes on to say in effect that he is hopeful that most of his colleagues believe that now is the time to act. I think that is one of the frustrations that this dialog illustrated for all of us.

Mr. Chairman, from personal experience that has dealt repeatedly with the kind of problem—and I am not just talking about the acid deposition problem, it is the problem of the tie between the need for scientific knowledge and the economic pressures in an environmental sense. As George put it so well, the things you can put a price tag on and the things that you cannot put a price tag on.

We debated probably 12 years in our State—a multimillion-dollar scientific versus economic debate—which was never really resolved over the carcinogenic effect of asbestos tailings from pacanite waste disposal in Lake Superior, a national issue, a national concern; and probably we did not resolve it to anyone's satisfaction.

We then debated in our State at great length and came up with a powerplant siting act, the need for nuclear power. Our State is 35-

percent nuclear powered and we have put in place an apparatus that addresses itself to the economic problems of doing this.

We have also been the scene, in our State, for probably one of the major debates over the transmission of direct current power, 440 miles of direct current electric transmission from lignite fields in North Dakota into Minnesota, passing over farmers who are still today, after 8 years, dynamiting power towers because the scientific knowledge that would tell them that their cows will not stop giving milk or whatever has not been agreed on.

I now find myself, as chairman of the Toxic Substances Subcommittee, preparing to deal with the whole issue of groundwater contamination from 15,000 pesticides.

Mr. Chairman, I think I well understand these concerns. But this experience just leads me to the notion that at some time we have to draw the line on the debate over the extent of the scientific knowledge that we need.

This is my first opportunity in this committee to speak on this issue. But I have gone back and I have reviewed all of the speeches you have listened to, Mr. Chairman, over the years. The record is already, it seems to me, replete with scientific testimony, and the weight of that scientific testimony would appear to be in the direction of the need to take some action and not debate it forever.

So, I hope that is the direction that we go.

Last week, Mr. Chairman, I introduced my own concept of how I thought we ought to go about this problem. I think it introduces some new concepts into the acid rain debate and in the course of that I found myself challenged by a few basic questions which I think all members of the committee will be forced to reconsider as we prepare the Clean Air Act amendments for the floor.

The first of those is whether a nation should make substantial reductions in the emissions of pollutants which are known precursors of acid deposition. The witnesses here this morning are going to update us on the science of emissions and deposition but, as I said before, I think the weight of evidence already in the record leads us to the conclusion that if we are going to protect natural resources, particularly aquatic resources on which the Nation puts a high value, then we need to make substantial reductions in sulfur dioxide emissions at an early date.

The problem is, how much, there is no magic number. I am a cosponsor of three different acid rain bills, one calling for 8 million tons a year, another 10 million, another 12 million. I am led to the conclusion by the wisdom of my colleagues that somewhere in that ballpark is the range necessary because the resources that we seek to protect in this country are not concentrated only in Maine or Minnesota, they are included in Montana.

The second question is whether or not we need a financing scheme as part of the program that we adopt. I look at the membership of this committee and I do not expect financing plans are going to be very popular. But, I will press for one. Partly because I think it will be necessary to get the bill to the Congress, and partly because I think a tax which spreads the cost of a control program is the only fair approach, and only a fair approach is going to solve the problem as this debate here earlier illustrated.

Control requirements cannot be evenly applied to everyone. As a practical matter, we will not go to every source of sulfur dioxide emissions in the Nation, or in the region, or of any region of the Nation, and require each to make a 40-percent or 50-percent reduction. It just would not be cost effective.

What will, in fact, happen is that a limited number of sources will be required to make very substantial reductions, maybe close to 90 percent, while others face no requirements at all. The type of industry, the age of the plant, the impact on jobs, the availability of a control strategy, all of these factors will dictate that control requirements apply in different ways at different sources—at least they should if we are trying to maximize the benefit we get for each dollar we invest.

But a strategy that selects a few plants in a few industries and makes those plants and their consumers bear all the cost is not a fair strategy. There are various ways to solve the fairness problem. I know the bill reported last year contemplates an emissions trading scheme. I would simply recommend to the committee that we do it in a more straight forward way with a tax and a trust fund that all can evaluate before the legislation is passed.

If you can agree that some kind of financing scheme is necessary, then the third question becomes, what kind tax mechanism we should use.

I was only able to identify three alternatives, dollars from the general revenue fund raised by existing taxes is one. Second, an energy or Btu tax, proposed on the House side or, third, an emission tax. I chose the emissions tax in my bill for three simple reasons.

First, it gives credit for what has already been done by many to reduce air pollution. My State and its electricity consumers have invested $300 million in sulfur dioxide scrubbers. That is a substantial investment. An electricity tax or general tax used to finance control technology in some other States would make my consumers pay twice.

Under an emissions tax, they will make a contribution because we still have emissions in Minnesota. But the rate of the tax will be substantially less as a result of this previous investment made by the people of my State.

Second, an emissions tax allows us to go beyond the electric utility industry to spread the cost of the solution to others who are clearly contributing to the problem.

My bill would cover sulfur dioxide and nitrogen oxide emissions from all major stationary sources and would include a tax on nitrogen oxide emission from mobile sources. By doing so, we lessen the obligations and evelate the opportunity for good of all who contribute to the problem.

Third, I think for the first time in our environmental control strategies we will put a price tag on the consumer and the purchase of public and private goods whose generation, manufacture, or propulsion has a dollar cost to our society in both an economic and an environmental sense.

Our colleague from West Virginia dragged out his $2,400 VEPCO bill and, if he were here I would just say that my bill would add a total of $35 a year to that VEPCO bill. It would add $17 to the price of a new car that one of these days, when he loses his limousine, he will have to purchase.

And all of that will free us of the smog that hangs over this city during the summer in particular.

Now, a fourth question is how to select the specific investments or retrofits that will be necessary to achieve substantial reductions. We are discussing a costly program, $30 billion to $40 billion worth of capital investment alone. If we do not apply control requirements carefully, or unless we allow some market mechanism to operate, we either spend substantially more than is necessary to achieve our goal or we get much less benefit than we should for the dollars we invest.

I do not know that the proposal in my bill, which is an instruction to EPA to prepare a priority list of investments, using a reductions maximinization rule to set priorities, is the best way to go.

But I would say to my colleagues that I do not have confidence in the approach reflected in the bill reported last year. It allocates reductions to State by an arbitrary formula and then requires States to determine where that allocation will become a specific control investment.

Unless we can demonstrate that this approach would be cost effective, I think we need to consider other alternatives.

Finally, Mr. Chairman, the fifth and the last question is whether we have the institutional ability to develop a controlled program at all. Bill Ruckelshaus has already described the acid rain problem as the most—and I think I am quoting him accurately—"most intractable political issue" he has ever experienced. That is maybe because of Don Regan and Dave Stockman. But I think it goes beyond that. As illustrated by the comments here this morning, we do have the potential to set one region of this Nation against another.

I think it is essential that this committee consider this fifth question along with all the others as it develops an acid rain bill.

Getting a solution to the acid rain problem depends upon the people sitting around this table in this committee. The expressions of parochialism, I guess, will in the long run, do us little good if we are to come to a consensus on some sort of a common ground because we are going to have to persuade the administration. We are going to have to persuade our colleagues in the House, and we are going to have to persuade the people of this Nation that acid rain legislation is a possibility or it will never come about.

So, Mr. Chairman, I hope that when we return for the second session of this Congress that you are going to put us on a forced march until an acid rain bill is signed by the President.

I personally am willing to commit some part of every day from now until that signing ceremony to be of assistance to you. I just wanted to use this occasion to make it clear to everyone that we are determined to produce legislation at the earliest possible date.

Senator **Stafford**. Thank you very much, Senator.

Senator Randolph?

Senator **Randolph**. I think that this is a time for a discussion, it does not need to be detailed. I think we ought to say to the American people, Mr. Chairman, that we are not going to be able to act in this committee this year on this subject.

I say that because I am realistic of the time element. But people continue to ask me, "Are you going to act on the acid rain legislation this year?" I have said to them that I could not see that in the framework of time that the Senate would act either in the reporting of the bill from this committee or within the Senate itself.

I think we must go back and remember that we passed our Clean Air Act in 1970 and then we passed the Clean Air Act again in 1977. We recall that it was last September when we reported S. 3041 which dealt with this specific subject matter to the Senate itself. There was no consideration of the legislation last year in the Senate.

Now that measure, we must for the record know, was reintroduced in this Congress and it bears the number of 768. Regardless of our position on this subject I say to Senator Durenberger, a very able member of this committee, coming aboard at this particular time, that there has been action within this committee on acid rain. I am not saying a consensus but the legislation had the necessary number to report it from this committee to the Senate itself, and that was September of last year, with no action being taken.

Mr. Chairman, I do not propose to think in terms of what you would say except to say that in my opinion we will be unable to report legislation this year. That it is important that we continue hearings this year and, that whatever is done, that this be a matter for early consideration in the Senate in 1984.

Senator STAFFORD. Thank you very much, Senator Randolph. The chair will comment that in light of the proposed pending date for adjournment sine die in the Senate this year if that is achieved or a date close to it is achieved, it would preclude any action on the part of this committee prior to early next winter.

We, in the meantime, do intend to have additional hearings. We had hoped to have one or two more in the immediate future. The only reason we have not is that we have run into scheduling difficulties with the scientists whom we wish to have here.

We are in some danger this morning of overrunning the time for a scientific discourse with us today, and I hope we will be able to get to it quite soon.

Senator MITCHELL. Mr. Chairman, could I just ask for a point of clarification?

Senator STAFFORD. Yes.

Senator MITCHELL. I believe the words you used were early next winter. May I assume from that you mean early next year, being this coming winter?

Senator STAFFORD. This coming winter, that is correct.

Senator RANDOLPH. We are in autumn now.

Senator STAFFORD. The record probably should show that the majority leader still has hopes—which may be justifiable—of getting us out of there on November 18, which is what I had in mind in the comments I have made.

Let me make one more brief comment and then we will get to the first panel. That is, listening to Senator Durenberger and the necessity for taking some action.

I agree. It occurred to me that we do not have the luxury of going to absolute scientific certainty about some of the scientific issues which exist here. I recall that the Senate and the Congress of the United States make decisions affecting very profoundly the course of this country on the basis of majority decisions in the Congress. In our court systems in civil cases, litigants who win do so by a "fair preponderance of the evidence." Even in criminal cases where the requirement for proof is higher, the decisions in our court systems are made upon evidence establishing the guilt or innocence of a respondent "beyond a reasonable doubt."

So, nowhere in our system do we, much as we would like it, have the luxury of absolute certainty in the decisions that we make.

Now, if there is no further comment, I would ask the first panel to come forward, Dr. Raphael Kasper, Executive Director, Commission on Physical Sciences, Mathematics and Resources, National Academy of Sciences, and Dr. Myron F. Uman who is the Executive Secretary, Environmental Studies Board, National Research Council, National Academy of Sciences.

Gentlemen, we will leave it to you to decide who goes first and who goes second. The Chair apologizes for the fact that always seems to face us, that we have insufficient time. I guess you have been asked to summarize in 10 minutes if you can, and we would appreciate if you could do that.

Mr. Uman. I will do my best, Senator.

Senator Stafford. All right.

Mr. Uman. I have a short prepared statement.

Thank you, Senator. The two of us will be delighted to answer questions at your convenience.

Senator Stafford. For the purpose of our reporter, would you identify yourself?

STATEMENT OF MYRON F. UMAN, EXECUTIVE SECRETARY, ENVIRONMENTAL STUDIES BOARD, NATIONAL RESEARCH COUNCIL, NATIONAL ACADEMY OF SCIENCES ACCOMPANIED BY, RAPHAEL KASPER, EXECUTIVE DIRECTOR, COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS AND RESOURCES, NATIONAL ACADEMY OF SCIENCES

Mr. Uman. My name is Myron Uman. This is Raphael Kasper.

I was the Staff Director of the Academy committee that wrote the report issued earlier this summer entitled, "Acid Deposition: Atmospheric Processes in Eastern North America." The chairman of that committee was Jack G. Calvert of the National Center for Atmospheric Research in Boulder, Colo. Dr. Calvert asked me to extend to you his regrets that he is unable to be here today. In his absence, it is my pleasure to tell you about the committee's report and to answer your questions.

In addition to Dr. Calvert, there were seven members of his committee. Their names and biographical data are listed in the report of which you have copies. The areas of expertise of the members include atmospheric chemistry and physics, meteorology, and modeling. All are actively involved in acid rain research. They come from universities, government and national laboratories, and the private sector. They have national and even international reputations in the field.

The committee was asked to look at only one specific aspect of the acid rain problem and that is the relationship between emissions and deposition. The committee did not, therefore—and it was not constituted to—look at questions dealing with effects of acid deposition or the costs and benefits of various acid deposition control programs.

Therefore, the committee was not in a position to make recommendations on whether a controlled program was necessary or desirable and did not comment on those issues.

The report focuses exclusively on current understanding of the atmospheric processes that transport emissions away from their sources, transforms them into acids and deposit them. It reviews theoretical understanding, the results of laboratory experiments and data obtained from observations in the field as well as models of the phenomena based on computer calculations.

The subject, as has been mentioned frequently here this morning, is a complex one; and that observation applies also to the atmospheric end of the problem. It is also true that the scientific evidence has been evolving rapidly.

The committee felt, however, that in order to make a positive contribution, its role should be to make its best scientific judgment about the meaning of current evidence. The committee was unanimous in its findings and conclusions and earnestly believes that its approach has been cautious and conservative.

The report addresses two questions that are central to the development of policy on acid rain control.

First, will a substantial reduction in emissions result in a commensurate reduction in deposition?

Second, to what extent are rural receiving areas influenced by small local sources or larger distant ones? In other words, will emission controls be effective and how important is long-range transport from major source regions?

The committee concluded that it is possible to give some answers to these questions but they are limited answers. For example, we know comparatively much more about the relationship between emissions of sulfur dioxide gas and deposition of sulfate ion, as in sulphuric acid, than about the relationships between emissions of oxides of nitrogen and deposition of nitrate ion, as in nitric acid.

We also know more about average relationships, say averaged over a year or more, than about specific events and episodes.

We know more about phenomena in eastern North America than elsewhere on this continent because monitoring and research efforts have been focused primarily in this region.

With these general cautions in mind, our findings can be summarized as follows: While emissions of pollutant gases do not vary much from day to day, acid deposition is highly variable. This is because atmospheric processes such as large-scale transport of air masses, atmospheric mixing near the Earth's surface, and physical and chemical reactions among atmospheric constituents determine where and how emissions are deposited.

These processes are highly variable, particularly in the parts of eastern North America believed to be ecologically sensitive to acid deposition. This variability complicates the analysis of source-receptor relationships.

While it has been hypothesized based on analyses of European data that the relationship between long-term average emissions and deposition is nonlinear, using the same type of analysis on North American data, the committee found no evdience for a strong nonlinearity in this relationship.

The finding is based in part on analyses of historical trends in emissions and deposition at one location in New Hampshire, the only site for which a reasonably reliable historical record is available in North America, in the judgment of the committee. It is also based on the analysis of the ratios of pollutants in emissions and deposition and their spatial distribution as well as on the comparison of the percentages of emissions of sulfur dioxide and oxides of nitrogen that are deposited as sulfate and nitrate in precipitation.

The finding is supported by theoretical calculations taking account of the latest results of realistic laboratory studies. In these studies, the chemical process widely hypothesized to introduce strong nonlinearity in the source-receptor relationship has been found not to be important in polluted atmospheres typical of eastern North America.

The report uses the phrase, "no evidence of strong nonlinearity." Why did the committee phrase its finding in this way and what does it mean? Let me try to explain.

Strictly speaking, the relationship between emissions and deposition is either linear or nonlinear. If it is linear, a change in emissions would result in a proportionate change in deposition. For example, if the relationship were linear and if a reduction in emissions of 20 percent were to lead to a reduction in deposition of, say, 18 percent, then a reduction in emissions of 40 percent would lead to a reduction in deposition of 36 percent. If this were the case, the constant or proportionality in the linear relationship would be 0.9. If the relationship were nonlinear, a change in emissions would result in a disproportionate change in deposition—or maybe even no change at all.

Now, we know that many atmospheric processes are in fact nonlinear. For example, the relationship between concentrations of ozone and other photochemical oxidants in heavily polluted urban atmospheres and emissions of the precursor gases from which the ozone is formed is known to be nonlinear. This nonlinearity contributes to the difficulties that have been experienced in controlling urban smog in some locations.

More to the point, historical data on acid deposition in Europe and a simple chemical theory developed in 1981 to describe the data have been widely used as a model for nonlinearity between emissions and acid deposition.

The committee started therefore from the assumption that the relationship in North America was also nonlinear and set about to determine how important the nonlinear processes were on the average. The committee looked for important nonlinearities in the available data, and within the limits of uncertainty associated with errors in the data and in estimating emissions, found none. This means that within the uncertainties and for average values and over large areas of eastern North America the source-receptor relationship can be taken for practical purposes as essentially linear.

But it is not possible to prove that it is linear, it is only possible to show that it is not strongly nonlinear.

I want to be as clear as possible about this conclusion. I can see I have not been so far. So, let me try again.

In performing its study, the committee took as its hypothesis the notion prevalent in early 1982 (when the committee was organized) that the relationship between emissions and deposition was substantially nonlinear. This hypothesis was based on data and theory developed in Europe. It is generally understood, however, that atmospheric conditions and the levels and spatial distributions of emissions in Europe are different from those in eastern North America.

Therefore, the committee tried to assemble all available data to test the applicability of a nonlinear model to our situation. The committee took an empirical approach, using two separate sets of data, one involving a time series at one location and the other the spatial distributions of emissions and deposition. In neither case are the data in eastern North America consistent with the nonlinear hypothesis.

As a result of the analysis of the empirical data, the committee decided that it should examine in some detail the theoretical model that was then current that indicated a nonlinear relationship. That examination revealed two deficiencies in that model, one having to do with assumptions about the natural background concentrations of sulfate in the atmosphere, and the other having to do with the chemical reactions included in the model and the respective rates at which those chemical reactions proceed.

In the first instance, the values of background sulfate that had been used were not appropriate for eastern North America. In the second, more detailed and more recent laboratory studies have shown that the chemical reactions leading to the nonlinearity are not important in eastern North America and therefore the revised model, when corrected as described in the report, gave a result that is essentially indistinguishable from linear.

The report does not attempt to explain the absence of a nonlinear relationship, other than the theoretical model which applies only to gas phase formation of sulfate. Indeed, the committee points out that the processes involved should, in general, be nonlinear. Certainly, the transport processes and the aqueous-phase formation of sulfate that is in cloud water are nonlinear in detail. Yet, for long-term annual average values, there is no evidence for significant nonlinearity. While this situation may look like an inconsistency, meteorologists among us are not surprised that some of the complications of the details are averaged out over the long term.

Now, was it appropriate for the committee to look at annual average values rather than detailed short-term events?

That probably is for you to decide. Clearly, as I mentioned earlier, the data are available on annual average values and data are not available to nearly the same extent on specific events.

Furthermore, there is substantial evidence from the biological community to suggest that it is the long-term accumulation of pollutants that has the most substantial effect. So, we looked at annual averages rather than at individual episodes.

Now, if I may, I would like to turn to the second conclusion of the report, that having to do with the relative importance of long-range transport from distant sources.

Theoretical and observational evidence exists for the long-range transport of air pollutants leading to acid deposition. There is little doubt of this. However, based on its analyses of both the available data and then currently available computer models of long-range transport, the committee concluded that the relative importance of long-range transport and the influence of local sources cannot be determined quantitatively with reasonable certainty at this time.

Computer calculations of the long-range transport of pollutants that lead to acid deposition currently are only very approximate. The committee concluded that the models are not sufficiently reliable at this time to provide realistic quantitative assessments over long distances.

Senator STAFFORD. Doctor, would it be possible—I realize this is a difficult request—for you to summarize now in about 1 more minute?

Mr. UMAN. I have very little else to say, Senator.

Senator STAFFORD. All right.

Mr. UMAN. So, Let me conclude by repeating that the findings of the committee, while important, have only limited applicability. We believe the report demonstrates that reductions in SO_2 emissions would lead to proportionate reductions in deposition of sulfate—with a constant of proportionality that is reasonably close to one.

We do not intend by this statement to imply that a policy of emission reduction is the best one to adopt because the committee did not look into the costs and benefits or other factors associated with pollution control policy.

The report can also be interpreted to suggest that if substantial reduction in SO_2 emissions are made nonuniformly within the study region, the integrated total deposition of sulfates in the region would be proportionately reduced. But in this case we cannot state quantitatively how large a reduction in deposition would occur in specific locations within the area.

Let me conclude my statement at that point, Senator, and Dr. Kasper and I will be glad to answer your questions.

Senator STAFFORD. Thank you very much, Dr. Uman. Dr. Kasper, we would be pleased to hear from you, if you have an additional statement.

Mr. KASPER. I have no additional statement.

Senator STAFFORD. All right. In that event, let me express the appreciation of the chairman of the committee to you both for being here, for testifying, and to the National Academy of Sciences for the effort that they have made in the report that has been presented to us.

If you could do this very briefly in view of our time constraints, would either of you recapitulate the history of the National Academy's report from beginning to end? I would like to know for the record the following specific information:

First, how many were selected to serve on the committee and how were those selections made.

Second, were there one or more peer review panels and if so, how many members were there and how were they selected.

Third, how many peer reviews were conducted, what were the results.

Finally, taking into account the number of scientists who served on either the committee or as part of the peer review process, how many can we honestly say contributed to the work product of the Academy?

Mr. **Kasper**. The Calvert Committee was established the same way the National Research Council establishes all of its committees. Upon identifying the problem, the Environmental Studies Board of the National Research Council, soliciting suggestions and nominations from members of the National Academy of Sciences, the National Academy of Engineering and a wide number of others outside the institution, established the committee of eight members, chaired by Jack Calvert, to perform the study.

The committee carried out its study over a period of probably 15 months or so. At the conclusion of that study and of any National Research Council study, a rather elaborate review process was undertaken to assure that the committee that had written the report took into account all the available data and argued correctly from that available data to its conclusions.

The review process that was used in this report was again the same as the review process used with any National Research Council report with one small exception, and that is that because we knew that this was an extremely controversial and important subject, we asked a somewhat larger group of reviewers to take part than we ordinarily would. In fact, there were something like 21 reviewers for a report prepared by a committee of only eight members.

Almost every one of those reviewers provided very detailed and informed comments on the report. The committee took the comments of those reviewers—which amounted to a volume that was about the size of the report—and considered every comment there. Many of them were accepted as constructive criticisms of the report; in a few cases the committee felt that the report adequately addressed the criticisms. The committee then revised the report.

Some of the reviewers, those that had the most significant comments on the first draft, then got a look at the revised report and then the report was released.

So, this is a report that was prepared through the efforts of an 8-member committee and 1 professional staff person working with that committee, which then was reviewed by 21 experts in the various areas it discussed—atmospheric chemistry, transport, modeling.

Senator **Stafford**. Thank you very much.

Senator Randolph?

Senator **Randolph**. One question only. Does the National Academy report suggest or support imposing controls on only four States, New York, Pennsylvania, Ohio, and West Virginia?

Mr. **Uman**. Senator, the report did not address the issue of what type of control program should be instituted, and did not analyze that option.

Senator **Randolph**. Thank you very much.

Senator **Stafford**. Thank you. Senator Durenberger?

Senator **Durenberger**. Mr. Chairman, I had the pleasure and the benefit of Dr. Uman's testimony as one of our subcommittee hearings a couple of months ago. So, I will forego any questions.

Senator **Stafford**. Thank you.

I would reserve, if there is no objection, the right of any members to submit questions in writing to both the doctors, if that is agreeable.

Mr. **Kasper**. Certainly.

Senator **Stafford**. Senator Mitchell?

Senator MITCHELL. Just as a followup to Senator Stafford's question. Over what period of time was the National Academy study performed?

Mr. UMAN. The committee was organized and held its first meeting in February of 1982. It issued its report in June of 1983. So, it was approximately 17 months.

Senator MITCHELL. Can you give us some idea of how much time committee members devoted to this study during that period of time?

Mr. UMAN. This is difficult to say because the members of the committee served pro bono. They do their work evenings, weekends, sometimes during their regular business hours. The committee held a number of meetings when the people were all brought together.

My guess would be that the average contribution of each member was probably on the order of roughly 2 man-days per month. It was a very intensive study. We had to gather the data, analyze the data oiginally because the data had not been analyzed in these ways before.

So, the average member probably spent 2 days per month over that 17-month period.

Senator MITCHELL. Are you satisfied that it is a carefully prepared, thoroughly thought-out work?

Mr. UMAN. The Academy is thoroughly satisfied in that regard, Senator. Dr. Kasper indicated that it was a very careful review and I believe the Academy stands behind the report.

Senator MITCHELL. You indicated there were 21 reviewers?

Mr. UMAN. There were 21 reviewers, yes.

Senator MITCHELL. Thank you very much.

Senator STAFFORD. Thank you, Senator Mitchell.

Senator Moynihan, I know you had a statement earlier or some comments you might have wanted to make. If you do, without objection, you might make them and we will place them with the opening statements, if you wish.

Senator MOYNIHAN. Mr. Chairman, I thank you. As you recall, I proposed the one bit of legislation we have enacted in this field, which was the Acid Precipitation Act of 1980. I would say basically, let us learn about the subject before we legislate on it.

I want to express great appreciation to the National Academy for this contribution we did not contemplate because we could not summon by fiat. It seems to me you have done an extraordinary piece of work here as a piece of the puzzle.

I will take a minute if I can because it seems to me that most science is a normal science, is incremental in this sort of thing. You have established the proposition of linearity and a proportionality constant of 1.0, which is really a big factor.

Can I just get it clear for the committee and for myself, your records were from Hubbard Brook; is that the site of the data?

Mr. UMAN. One set of data was from Hubbard Brook, yes, sir.

Senator MOYNIHAN. That is a Cornell operation, is it not?

Mr. UMAN. It is a U.S. Forest Service experimental facility. The atmospheric deposition work is going on there cooperatively between Yale University and Cornell University.

Senator MOYNIHAN. Yes. Now, I would like to be clear what it is, we have a simple curve here and you have an x-axis and a y-axis. The y-axis is basically what has landed in this forest in New Hampshire by way of sulfate.

The x-axis is what? That is the total amount of emissions in the region and, as it were, what region? You tell me what is proportionate to what.

Mr. **Uman**. Well, if you will indulge me for a few minutes, Senator, I just happen to have the graph here.

Senator **Moynihan**. Yes. I guess my question is, what is proportionate to what in your finding? You found a linear proportionality between what and what?

Mr. **Uman**. Well, let me preface my remarks, Senator, by saying that the chemistry that is involved in the atmosphere is very complicated——

Senator **Moynihan**. And frequently nonlinear.

Mr. **Uman**. And frequently nonlinear. The hypothesized nonlinearity arises because of the emissions of nitrogen oxides because nitrogen oxides compete with sulfur dioxides for reaction with the oxidizing agents that are in the atmosphere.

So that the more nitrogen oxide you have, the more substantial the nonlinearity effect should be with respect to the oxidation of sulfur in the atmosphere.

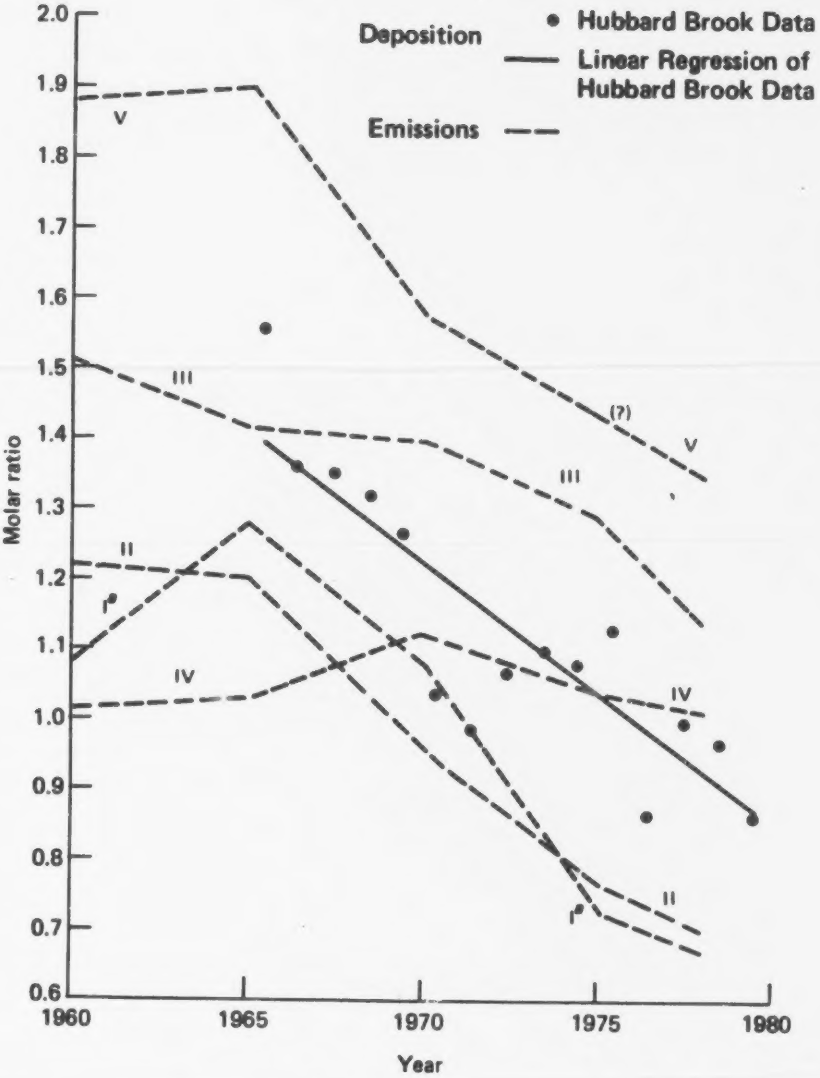
So, what the committee did at Hubbard Brook—and I want to emphasize that this is only one of several pieces of information used in the study—was to look at the ratio of sulfate and nitrate in the deposition.

This figure comes from the report (figure 4–19, exhibit A attached). The x-axis is time, and the y-axis is a ratio of sulfate to nitrate in the deposition at Hubbard Brook. The data, which showed typical meteorological variability, are the black dots.

EXHIBIT A

to the

Testimony of Myron F. Uman



* Excludes Vermont.

Mr. **Uman**. The solid line is the least squares fit the appropriate statistical analysis of these data and shows that there has been a decrease in the ratio of sulfate to nitrate in deposition at Hubbard Brook over that period of roughly 15 years.

In detail, if you look at the chemistry, the decrease is owing to a small decrease in sulfate and a larger increase in nitrate. In fact, the numerator has been going down and the denominator has been going up. That makes the ratio go down.

The reason this is important is because it is the denominator that influences the nonlinear effect. The process should be more and more nonlinear the more and more nitrate is present.

Now, we analyze these data using the only statistical technique that——

Senator **Moynihan**. Least squares.

Mr. **Uman** [continuing]. The least squares fit. Now, the dashed lines show the molar ratio of sulfur dioxide to nitrogen oxides in emissions. The dashed lines are what goes up; the solid line is what has come down at that one location.

Now, I do not know whether you can see this from where you are. We had a larger version but EPA stole it. [Laughter.]

Mr. **Uman**. There are some Roman numerals on the side here. they indicate EPA regions. These are the emissions ratios by EPA region.

Region I, which is this line—and I ask if you possibly can to ignore the emissions data prior to 1965 because we do not have deposition data there, we are only talking about here over.

Senator **Moynihan**. Yes.

Mr. **Uman**. OK, because we do not have any deposition data over here. But this is region I, which are the New England States except that Vermont's contributions were not included in the data because they are so small.

Region II is this line here. That is New York and New Jersey.

Senator **Moynihan**. So, you get that equivalent linear, if you split it even, you get the same lines.

Mr. **Uman**. These are straight lines drawn between consistent estimates of emissions at different times provided by consultants to the EPA.

Region III is the Middle Atlantic States, that is this line over here.

Region IV is the Southeastern States——

Senator **Moynihan**. And you do not find it there.

Mr. **Uman**. You find something quite different here. Region V is generally the Ohio River Valley.

So, from this chart and given the statistical uncertainty in the data and in the curve fitting for the analysis, it is not possible to distinguish between the slopes of the solid line and the dash lines for region I, region II, region III, or region V.

So, from this analysis it is not possible to tell where the deposition in Hubbard Brook is coming from. But the analysis is convincing that the deposition at Hubbard Brook has responded to changes in emissions in a fashion which reflects them directly. There is no evidence of nonlinearity in these data.

Senator **Moynihan**. That is a hugely elegant analysis, really. Congratulations, that is nice work. Now we have to go to the whole question of determining atmospheric transport which is being done by that immensely elegant study.

I will now stop, Mr. Chairman, but I just want to see if I can do this—releasing traces of perfluoromonomethylcyclohexane——

Mr. UMAN. Excellent.

Senator MOYNIHAN. Did I get it? You are familiar with that project.

Mr. UMAN. There are probably others in the room who can speak on that.

Senator MOYNIHAN. Do you have any idea what time we can expect any early readings?

Mr. UMAN. The Calvert Committee in its deliberations discussed the question of how long it might take to obtain more refined data that might change its conclusion. Given the meteorological variability and the climatalogical variability from year to year, their conclusion was that field tests would probably have to go on for the order of 5 to 10 years before we had sufficiently refined data to have a better air quality model to use for predictive purposes.

It is a combination of development of the models and the field data which can be used to refine and test the model.

Senator MOYNIHAN. We might come back to this, Mr. Chairman, because that is important, the 5 to 10 years.

Thank you very much.

Mr. UMAN. This number is not in the report, I should add. I am just telling tales out of school.

Senator MOYNIHAN. Thank you very much, both; that is really nice stuff, really.

Senator STAFFORD. Thank you very much, Senator. The question of emissions and a linear progression to deposition on the evidence I just heard reminded me a little bit about that old saying of a skunk at a lawn party. You may not be able to tell where it is, but you sure know it is there. [Laughter.]

Senator STAFFORD. Senator Baucus?

Senator BAUCUS. Thank you, Mr. Chairman.

Doctor, as I understand it, you are saying that your study shows there is no nonlinearity; is that correct?

Mr. UMAN. There is no evidence of a strong nonlinearity. You know, the data are not so precise that there could not be a small nonlinearity, but not one that is sufficiently important to be concerned about.

Senator BAUCUS. I am curious, did you look for a linearity? Did you establish a linearity hypothesis and then try to test that out to see if that makes any sense? I know the way they went. I am wondering why they did not go the other way.

Mr. UMAN. Well, there is good reason for that. When the committee started out it was a general consensus of scientific opinion everywhere in the world that the relationship should be nonlinear. So, the committee members in fact started out assuming that it was nonlinear. Their original objective was to say, well, how important are the nonlinearities.

For example, this is part of the discussion of our very first meeting: Would a 50-percent reduction in SO_2 emissions lead to a 5-percent reduction in acid formation?

These were the numbers they were talking about. They recognized that the data that were available in North America had not been analyzed in the same way that the data in Europe had been analyzed. So, they set about to gather and analyze the data in that way to try to estimate how important the nonlinearity was.

They found just no evidence of the nonlinearity at all. They thought it was quite a surprise. So, they went back and looked at why they found this, and discovered several reasons why there might be differences.

One is that the parts of Europe that have been studied are farther north in latitude than the parts of North America where the acid deposition problem is supposed to be occurring. That means they have less sunlight, and sunlight is important for the photochemical processes.

Senator BAUCUS. If my understanding is correct—and perhaps I am wrong, I have not had a chance to study the next witnesses' testimony—it is my understanding that the people at the Brookhaven National Lab feel that there is nonlineary.

But as you are saying, there is no good evidence of that. That looks like a different point of view; is that correct?

Mr. UMAN. Senator, first of all, let me say that Dr. Calvert did have an opportunity to see the comments that were prepared by the group from the national laboratories and has prepared for submission to the House a rebuttal of that. If you would like it for the record, I would be glad to submit it to you.

Senator BAUCUS. If you can just describe the reasons for your different points of view.

Mr. UMAN. The answer, Senator, is that everyone in the atmospheric science community understands that in detail the processes are nonlinear; that is, if you look at small time scale, small spatial scales, we know that the meteorology is nonlinear.

Senator BAUCUS. But in this case there is no evidence.

Mr. UMAN. I have not finished yet.

Senator BAUCUS. All right.

Mr. UMAN. If we were to look at specific episodes, we probably would find some nonlinear effects. But if we look at annual average values, we do not see them.

This is not uncommon in climatology and meteorology. The fact that it rains here and not there on a given day, is determined by very, very complex nonlinear processes.

But on the average it rains roughly the same over time. We have a pretty good climatology. Now, it varies somewhat from year to year and we have to worry about that. But it rains.

Senator BAUCUS. Again following up Senator Mitchell's question, how much time did they spend. You said 2 man-days per month?

Mr. UMAN. Well, that is two per person. That is 16 man-days per month over an 18-month period. That is not counting the time spent by the 21 reviewers who probably each spent a week.

Senator BAUCUS. Do you feel comfortable with that amount of time? Do you feel you reached diminishing returns with that amount of time, or you would not have reached diminishing returns if they doubled or tripled the amount of time spent on it?

Mr. UMAN. I think the committee is quite comfortable with its conclusions.

Senator BAUCUS. So, you feel it was reaching diminishing returns. You mean the data available would not have made that much difference to the study.

Mr. UMAN. The committee examined all the data that were available to it. Those data were central to the conclusions reached. It is always helpful to have more data, but more data were not available in this case.

Senator BAUCUS. Thank you.

Senator STAFFORD. Thank you, Senator Baucus. Senator Burdick?

Senator BURDICK. Thank you, Mr. Chairman.

I would like to touch upon a point that was raised in questioning by the Senator from New York.

In your statement, you say,

> However, based on its analyses of both the available data and current available computer models of long-range transport, the committee concluded that the relative importance of long-range transport and the influence of local sources cannot be determined with reasonable certainty at this time.

You touched upon that in your answer and you indicated that it may be 5 or 6 years before you can get that certainty?

Mr. UMAN. Five to ten years, Senator.

Senator BURDICK. Five to ten years. Thank you.

Senator STAFFORD. Thank you, Senator Burdick.

Senator MOYNIHAN. Could I just ask one other thing?

Senator STAFFORD. Certainly.

Senator MOYNIHAN. This committee is not noted for the number of physicists on it and we try our best. Last year in our clean air hearings, we had a great time trying to get it straight that a linear relationship need not have a constant proportionality of 1.0.

Mr. UMAN. That is correct.

Senator MOYNIHAN. When you were saying earlier to questions that a 50-percent reduction in emissions might lead to a 5-percent reduction in the actual deposition, that could be a linear relation, too.

Mr. UMAN. It could be, that is right.

Senator MOYNIHAN. That was a constant proportionality of 0.1.

Mr. UMAN. Yes.

Senator MONYNIHAN. But that would tell you, you are not going to get a lot of reward at this end for what you do at that end.

Mr. UMAN. That is correct.

Senator MOYNIHAN. But what you have found out is that whatever it is that is going on here, if you change over here, you will get something very close to the unity in the changeover in the results over here.

Mr. UMAN. It depends on how you make the change, Senator. That is, the relationship is one between the emission averaged, totaled over the year, and deposition totaled over the year. So that changing emissions by, say, 50 percent in only one place and changing——

Senator MOYNIHAN. Oh, no, I got you there.

Mr. UMAN. OK.

Senator MOYNIHAN. But if you are right, we have found out that it is possible to have a large effect on these outcomes if you go about it right.

Mr. **UMAN**. That is correct. Essentially, what it says is that as far as the sulfur system in eastern North America is concerned, that portion of the sulfur that comes down in eastern North America responds linearly with the emission levels. So that a reduction in emissions level would provide a commensurate benefit.

Senator **MOYNIHAN**. On my part, I would like to say the Academy has, not for the first time, done a very fine piece of science. That does not surprise you, maybe, but it pleases certainly this Senator and I want to thank you.

Mr. **UMAN**. It pleases us to know that you think so, Senator.

Senator **STAFFORD**. Thank you, Senator Moynihan. I certainly concur also. We are often in the debt of the Academy for the many scientific investigations they have made for this committee and for the Nation.

We thank you both very much indeed.

We now invite the second panel to come forward, Mr. Manowitz, chairman, Department of Applied Science, Brookhaven National Laboratory; Dr. Jack Shannon, meteorologist, Environmental Research Division, Argonne National Laboratory, and Dr. Michael Oppenheimer, a senior scientist, Environmental Defense Fund, New York, N.Y.

Gentlemen, it might be well to go in the order in which you have been named which means, Mr. Manowitz, you would go first. We would ask you, if you can, to limit your statements to not to exceed 10 minutes.

Your statements in the possession of the committee will be made a part of the record in full. A rebuttal of Dr. Calvert which was mentioned by the earlier witnesses, without objection, will be made a part of the record, although the committee hopes to get the doctor in front of it as a witness before we conclude.

Mr. Manowitz, we are ready to hear you.

STATEMENT OF BERNARD MANOWITZ, CHAIRMAN, DEPARTMENT OF APPLIED SCIENCE, BROOKHAVEN NATIONAL LABORATORY

Mr. **MANOWITZ**. My name is Bernard Manowitz. I am the chairman of the department of applied science at Brookhaven National Laboratory.

I am also the chairman of the National Laboratory Consortium, a group of four national laboratories that are a congressional mandated part of the Interagency Task Force on Acid Precipitation.

I have been asked by this committee to discuss the nature and conclusions of the National Laboratory Consortium's review of the recent report on acid rain issued by the National Research Council.

What I would like to do at the very outset is to indicate that I know every member of the committee of the National Research Council, respect them, and agree that they have fine international reputations.

I would like to say at the very outset that most of the work that has been presented in the Academy report is indeed very valuable and very useful. However, I am in the unenviable position of representing a group of scientists in the national laboratories that disagree with one of the major conclusions of the National Research Council's report.

A principal conclusion of the NRC committee regards the relations between sulfur dioxide emissions and deposition. The chairman of the National Research Council states in his forwarding letter that it is the committee's judgment, "That if the emissions of sulfur dioxide from all the sources in this region, northeastern North America, were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition." Such a corresponding reduction would be characteristic of a linear and proportional relationship, as Senator Moynihan has pointed out.

However, the National Laboratory Consortium disagreed almost uniformly with this conclusion and with the methods used to reach this conclusion.

I presented the detailed points of different reviewers from the national laboratories in the document that we presented to be put into the record.

If you can indulge me for a few comments, I think I can best describe the evidence that the NRC committee presented and the evidence that the National Laboratory Consortium believes disputes that conclusion, by a series of viewgraphs.

What I have done is to prepare copies of those viewgraphs which I will be happy to distribute to the members of this committee.

These viewgraphs actually are taken directly from the Academy documents.

Senator STAFFORD. Doctor, it is even harder to read up-side-down.

Mr. MANOWITZ. On page 8 of the committee's documents they indicate that there is evidence for strong nonlinearity in Europe. This is indeed the evidence that has been presented.

Let me draw your attention to the last few lines of the viewgraph on European data. That indicates that the molar ratio of sulfates to nitrates varies in such a way that it is increased from a value of 1.8 to a value of 3.6 in the time period of 1955 to 1959.

This is the evidence that the committee believes is indicative of a nonlinear relationship. The question is, do we see any similar evidence within the United States or within the North American continent. In the next viewgraph, what the committee based its principal conclusion on are these data taken from a series of eight or so different stations, essentially within the United States.

Senator BAUCUS. What does "molar" mean?

Mr. MANOWITZ. I am sorry?

Senator BAUCUS. Molar ratio, what is it?

Mr. MANOWITZ. I have to describe what a "mole" means, I guess, to you. This is an equivalent relationship between the amounts of sulfate and nitrate. It bears back to the molecular weight of that particular compound, and it is equivalent to one molecular weight of a compound dissolved in a certain portion of water. That would be one molar amount of that particular material.

So, it is a way of describing the ratio of the sulfate and nitrate in this case in rainwater.

The principal evidence that the committee has used are the annual average data that are shown in the right-hand portion of this viewgraph. As you can see, the annual averages are indeed constant and, if these were the only data presented, would provide at least one basis for evaluating the hypothesis that the committee has come up with.

The committee, however, provided additional information to substantiate their hypothesis—I hope I can now get this the right way—and these again are data taken exactly from the committee report.

Now, the point that is made in this viewgraph is that if you look at these numbers at the same places that the stations were taken previously, the numbers indeed are relatively constant. They are approximately one.

However, the NRC committee was kind enough to put isopleths on the data that extend throughout the North American continent. I think you can see by looking at these waved lines with a number on the outside which are lines of equal molar ratios that indeed some place in the western Pennsylvania region the values are about .8, .9. As we go up farther toward Maine, the numbers are 1.2. Up to the top of Maine, we have numbers of about 1.6.

So, indeed, we do get values, gradients, within these data very similar to the gradients that were observed in Europe that were also observed in this particular case for one particular year. But there is no reason to suppose that these gradients would not also be evident in another year if that year were to be looked at.

So, we believe that the very data that the committee has used to substantiate linearity also substantiates a nonlinear interpretation of these data.

Now, Dr. Calvert in his response, as you will see, objects to the gradients that have been described here and proposes that if one took the origin of the data in the Ohio Valley rather than in western Pennsylvania, then the data could be interpreted as being more linear.

The point that the National Laboratory Consortium would like to make is that if these data are so sensitive to the location of the origin, then the data and the validity of the argument itself is somewhat suspect.

Now, the other piece of information that was presented by the Calvert Committee had to do with the same curve that you have seen previously. It is this relationship at Hubbard Brook that indeed shows the deposition data compared to the emissions data, and the solid line is the linear regression of the points that are seen there, the individual data points having to do with deposition at Hubbard Brook.

Indeed, the NRC committee provided an uncertainty analysis of the deposition data and we will accept their values that indeed there is a depression in the data plus or minus the values that the committee has indicated.

However, in giving the data on emissions, there has been no uncertainty analysis. And indeed, as has been pointed up by one reviewer of the National Laboratory Consortium, it is known that the emissions data vary very considerably. So that without an appropriate uncertainty analysis of those emissions data it is very difficult to say whether this trend is an artifact or whether indeed the trend is real.

So, that is one argument against the data that has been used at Hubbard Brook.

There is yet a further argument, however, and this gets down to the impact of linearity versus nonlinearity. What I have drawn here is a transect across the United States and you can see the transect as indicated by the line A–B.

The top curve in the bottom portion of this graph is an indication of the current concentrations of sulfate in precipitation across that particular transect, and you can tell that in the Ohio Valley the levels will be higher than they will be in Maine or that they will be in the south part of the United States. We will always get this sort of a bell-shaped curve.

Now, I call your attention to the dotted line which is indicated as linear. The hypothesis is made here that if there were a 50-percent reduction in emissions, then across this entire region, if the mechanism was linear and proportional, one would anticipate that at every point one would get a 50-percent reduction in the deposition.

On the other hand, if the mechanism were nonlinear, then in the central region, in the near emissions region, one would anticipate a very small amount of reduction in the amount of sulfate in rainwater, but by a material balance someplace within this system, if the system is sublinear in the central region, in the far out regions it would have to be hyperlinear. That is, what goes up, goes down. It has to come down somewhere.

What this implies is that if we try to get a relationship between a linear and a nonlinear mechanism, someplace in the out regions it will be difficult to tell the differences between linear and nonlinear because these two lines cross.

The National Academy made their evaluation based on one point, the point at Hubbard Brook. The question we raise is, is it possible that Hubbard Brook is in this region where the data are ambiguous and where it is difficult to tell whether or not the mechanism is linear or nonlinear.

Senator STAFFORD. Would it be possible, doctor, to summarize here in the next minute or 2?

Mr. MANOWITZ. Yes, I can.

It is very brief. The National Laboratory Consortium does not dispute that the system may be linear. The only point they make is that the conclusion that has been presented by the National Academy thus far is an unproven hypothesis. It is an interesting hypothesis but at this point the entire story is not known.

Senator STAFFORD. Thank you very much.

Why not go ahead with the next witness who would be Dr. Shannon?

STATEMENT OF JACK SHANNON, METEOROLOGIST, ENVIRONMENTAL RESEARCH DIVISION, ARGONNE NATIONAL LABORATORY

Dr. SHANNON. Thank you. I am Jack Shannon from Argonne National Laboratory. I have been involved primarily in modeling of long-range transport and deposition for the last 8 years, with obvious emphasis on aspects of the acid deposition question.

A number of the comments that I would have—and they are in my written testimony—related to the NRC report were included in Bernie Manowitz's testimony just now. So, I will not repeat them.

I will say that in general I find the conclusions of the report reasonable. Indeed, in the modeling that I do, I have assumed a linear relationship between emissions and deposition all along. So, in that sense it is in my interest that the report be correct.

However, for a number of the reasons mentioned by Bernie Manowitz, I do not find the results conclusive. I find them reasonable. I actually hope they are correct, but I do not find them conclusive.

I am bothered more by some of the comments on modeling and the use of modeling, particularly in examination of source-receptor relationships, such as the deposition from a source region like southern Ohio to the Adirondacks because that is the kind of calculation that I make much of the time.

Senator Mitchell had mentioned how difficult it was to quantify damage costs, or benefits if you alleviate the damage, while the costs of a control action are much more easy to quantify, for example, $100 million for a particular scrubber.

The situation is actually worse than that, because you have to estimate the benefits of the action for the future and you do not know what future conditions will hold. So, that adds even more uncertainty.

However, there is no coherent way to balance the cost of controls and the cost of unemployment in the coal industry against ecological or material benefits, without doing assessments. There are uncertainties all the way along the assessment process. We are working on reducing uncertainty, but we still have a long way to go.

I do feel that our current models provide useful information. Indeed, I have given information upon request to such groups at the Office of Technology Assessment. Some of the information has been passed on to some of the Senators, perhaps.

If a proposed action should include provisions for a common fund, a Superfund from all users of electricity or an emissions tax, such that an emission source taking an action does not have to finance all of the control costs, then interstate trading and least-cost control strategies become much more attractive and likely.

We have done a number of studies of Argonne recently, work is still in progress—looking at some of the legislative proposals and examining what would happen if instead of requiring a roughly uniform emission reduction by State according to the formulas as they are written in the proposed legislation, we were to shift the emission reductions around to get the greatest benefit at least cost according to some deposition-reduction target.

Now, it then becomes very critical as to how that target is defined. For instance, if you wish to reduce at the deposition in the Adirondacks and you are not concerned about what your action does or does not do in the Smoky Mountains or in the boundary waters, just concerned with the Adirondacks, if pressed most scientists in the field would agree that a least-cost strategy would be to control emissions in western New York, Pennsylvania, Ohio, and West Virginia.

As it turns out, if you include New England with the Adirondacks in your deposition-reduction target, your least-cost strategy is fairly similar. You would wind up imposing more controls in Massachusetts and Connecticut, perhaps. But there are not that many emissions to the northeast of the Adirondacks.

However, once you start including other geographically separated target areas, such as the boundary waters, then a control strategy optimal for the Adirondacks is not going to be optimal for the boundary waters.

Senator MOYNIHAN. I did not hear that.

Dr. SHANNON. If you were trying to reduce acid deposition by a certain amount in the boundary waters——

Senator MOYNIHAN. Oh, you mean the Great Lakes.

Dr. SHANNON. For deposition in the boundary waters in northern Minnesota, emissions controls in West Virginia, for instance, according to the calculations I make and others make, will have very little effect and you might want to concern yourself more with emissions controls in North Dakota, among other places, because of geographical proximity.

So, the kicker in optimal strategies is in definition of the target, whether you narrowly limit where you are trying to reduce acid deposition or whether you optimize reductions over a very broad area.

Perhaps in the interest of the time constraints with which we are faced, I would like to summarize my opinion as to the value and use of models. The NRC committee is correct in advising caution in the use of current source-receptor models. Model limitations should be considered and indeed are considered in proper assessments.

However, if the recommendation of caution implies a recommendation that current models not be utilized in policy analyses or that no emission control action be taken until some future date at which time better or more sophisticated models are available, I strongly disagree. We can perform useful modeling exercises now and the results of those exercises should be available to those who must determine whether to mandate emission controls and if so, where and when.

Senator STAFFORD. Thank you, Dr. Shannon.

Dr. Oppenheimer?

STATEMENT OF MICHAEL OPPENHEIMER, SENIOR SCIENTIST, ENVIRONMENTAL DEFENSE FUND

Dr. OPPENHEIMER. My name is Dr. Michael Oppenheimer, I am a senior scientist with the Environmental Defense Fund. I am an atmospheric physicist and I am testifying at the last minute at the invitation of the committee, so I do not have a prepared statement to submit.

I was asked to testify on the Calvert Committee report and the National Lab Consortium comments on that report.

I want to point out that I have been doing active research for 3 years on the question of linearity, have published three articles which are, as far as I know, the only quantitative analyses in the peer reviewed literature on the question of linearity in Eastern North America.

I am a member of the ad hoc committee that reviewed the national acid precipitation assessment program—also known as the Deutch Committee—which operates under the Science Advisory Board.

I want to emphasize that I participated in the meeting, that the National Academy of Sciences put together, of about 14 scientists, at the invitation of Mr. Ruckelshaus, to advise Mr. Ruckelshaus on this issue. At that meeting all the scientists assented to the proposition, the main proposition in the Academy report that the linearity question had essentially been put to rest—at least in the sense that the Academy was addressing it. That is, there are no significant nonlinearities. Dr. Shannon was there on that day, I believe.

As I said, I have read both the Calvert report and the National Lab's response to it. There are basically several questions we want to ask today. The Academy had the following purpose: To determine the effect on acid deposition of large-scale emissions reductions.

The nonlinearity question arises, as Myron mentioned before, because of both the European data and the general suspicion that at a microscopic, molecule-to-molocule level, these processes are nonlinear.

So, the questions that one needs to address about that analysis are: Was the analysis that was performed adequate and is the conclusion valid?

Second, is there any relevant or new information in the National Lab Consortium comments that would change those conclusions?

On the question of adequacy, I would merely point out that there are essentially five different arguments in the Academy report on which the linearity conclusion is based. I will not go into them in detail because most of them have been discussed already today.

There are at least four different sets of data on which that conclusion is based. All five separate analyses are consistent with the conclusion of a linear hypothesis and they are all essentially inconsistent with the existence of any significant nonlinearity.

There are uncertainties in this analysis but the analysis is both reasonable, original, and thorough given the current limitations on available data and the question that was asked of the committee, that is, to address the relationship between emissions and deposition on a macroscopic level.

So, the undertaking of the committee was appropriate to the task.

Now, is the analysis valid? One can compare one analysis with other analyses of this question. First of all, it should be pointed out that no convincing evidence of a significant nonlinearity in the atmospheric chemistry of sulfur over Eastern North America has ever been presented by anyone anywhere, anytime.

Second, the so-called European evidence has been misinterpreted, and in the original paper that presented that evidence—by Granat, in 1978—there was no explicit inference of nonlinearity from the data. The nonlinear relationship between historical emissions and deposition which is inferred from that data by some is a gross misinterpretation, essentially because the data is totally inadequate to make such an inference. There is not a good superposition of deposition networks with emissions data in Europe.

Third, as I said, I have published articles in the scientific literature indicating, as a separate piece of evidence and using methods which are entirely different from the Academy's, that a 50-percent regionally averaged emissions reduction would produce a 40 percent or greater regionally averaged wet deposition reduction.

Fourth, the only other overall review group to address this question was the so-called experts' meeting at the Stockholm conference of 1982, and they also agreed that the regionally averaged relationship between emissions and deposition is approximately linear.

Finally, I would point to another piece of evidence, the relative success of Jack Shannon's and other people's long-range transport models in reproducing deposition patterns. These models generally use a linear assumption.

Now, to the National Lab Critique. The people who worked on it—several of them are friends of mine—are good and honest scientists. Some of the points are good. On the other hand, some of the criticisms are totally intemperate, out of context and uncalled for.

It is easy to take potshots at an analysis as complicated as the Academy's, but I want to point out that there is no significant alternative proposal in the criticisms. There is no real alternative model proposed and, again, it is a matter of criticizing a document without proposing an alternative analysis which really shows anything different.

The one attempted statistical analysis in the criticisms is, as far as I am concerned and as far as Jack Calvert is concerned also, totally worthless.

So, why is there a problem? Why are reasonable scientists appearing to disagree on this issue?

I think the origin of difficulty can be found in the difference between so-called microscopic and macroscopic issues. That is, the National Academy was asked to address a question of what would happen to deposition over substantial geographical areas, if emissions were changed. They were not really asked to address the question of the microscopic behavior of atoms and molecules.

The National Lab critique raises some significant questions about those microscopic issues, but they are probably not particularly relevant to the question of policymaking on acid rain. Acid rain is a macroscopic problem in space and time.

There are some criticisms in the National Lab review which have some validity, which relate to the treatment of data. The National Academy analysis is not perfect in that respect. There are some places they could have indicated their uncertainties a little more clearly and they did not do so. However, in general, I would say the criticisms are, though interesting, not a fundamental challenge to the report's conclusions.

So, in conclusion I would say that the Academy is certainly correct, if one weighs the report against all existing data that the Academy studied and all the other existing data, plus all the other reviews of the subject—including my own—the Academy is correct that there are no significant nonlinearities in the atmospheric chemistry of sulfur over significant space and time scales over eastern North America.

It is not the final word on the issue. It is not a perfect analysis; we need to know more. There are interesting questions about further research possibilities which are raised in the National Laboratory critique which, I think, need to be pursued. We need to have further research on these questions.

But the Academy has taken a very good first cut, I think that criticism is healthy, but I think that the first cut stands on its own and we need to thank the Academy for doing such a fine job on what was a very complicated problem.

Senator MITCHELL. Thank you very much, Dr. Oppenheimer.

Mr. Manowitz, I would like to begin with some questions of you. As I understood the Academy report, it concluded that there was no evidence that SO_2 emissions to sulfur deposition process is nonlinear in North America, and it makes reference to a European study which you presented a slide of as purporting to represent evidence of nonlinearity in Europe. Is that correct?

Mr. MANOWITZ. That is correct.

Senator MITCHELL. I would like to ask you with respect to that European study, since you have cited it here today I presume you have reviewed that study and are satisfied with its accuracy.

Mr. MANOWITZ. I have indeed read the documents involved and I am satisfied essentially it was accurate.

Senator MITCHELL. Can you tell us, please, whether or not the emissions trends in that study cover all of Europe?

Mr. MANOWITZ. The emissions trends in that study start in the general area of Great Britain and in the Ruhr Valley, which is point 1 as indicated in the slide that I gave you.

The next data points, essentially, are in Denmark. Then there are three other regions in southern Sweden, going from that particular point all the way up to northern Sweden and to the Norway region. So, they do not cover all of Europe but they do cover a substantial fraction.

Senator MITCHELL. Well, are there not in that study emission sources in southern Europe?

Mr. MANOWITZ. Yes, there are.

Senator MITCHELL. There are.

Mr. MANOWITZ. And in eastern Europe.

Senator MITCHELL. And that, of course, tells us what the emissions trends are and the source of information comes from all of the areas described, northern, southern, and eastern Europe.

Mr. MANOWITZ. That is correct, sir.

Senator MITCHELL. Now, with respect to the monitoring network involved, can you tell me where the monitoring network involved in that European study is located?

Mr. MANOWITZ. It is located more throughout Europe, actually. The heaviest monitoring network is in the Scandinavian countries. But there is also a monitoring occurring in Great Britain, in the Benelux countries, and in Germany.

Senator MITCHELL. Is it not true that there are no monitoring points in that study in southern and eastern Europe?

Mr. MANOWITZ. There may be, but those data are not reported in the European study. Particularly, there is no information from eastern Europe available.

Senator MITCHELL. So, the European study reports emissions from an area that includes northern Europe, southern Europe, and eastern Europe and reception from an area that includes only northern Europe; is that not true?

Mr. MANOWITZ. Not exactly, sir. The data indicate reception wherever the reception happens to come from. In other words, the monitoring data simply accept the values in the samples that are taken at that point.

Senator MITCHELL. But the points in which the data was received were not coterminus with the area from which the emissions were measured; is that not true?

Mr. MANOWITZ. From which the emissions were measured, or from what the emissions resulted? In other words, what is true is that the terminus of the deposition data reflects all emissions that happen to come to that particular point.

Senator MITCHELL. To that particular point.

Mr. MANOWITZ. To that particular point. Emissions were measured, however, only in a portion of Europe, not in the entire European Continent.

Senator MITCHELL. Well, the point I am making is that I believe that a very valid argument can be made—and I intend to have one submitted for the record—which explains the European study on the basis that the emission increases may have occurred in parts of Europe which do not have adominant influence on the monitoring network which was in a much smaller portion.

Mr. MANOWITZ. That is entirely possible.

Senator MITCHELL. Right. And that is the only study, to your knowledge, that establishes the principles of nonlinearity; is that not true?

Mr. MANOWITZ. It is not my claim that that study establishes the principle of nonlinearity. I simply quote the information in the Academy report. It is their claim that that study establishes nonlinearity, not the National Laboratory's.

Senator MITCHELL. Well, you have supervised an effort to criticize what Mr. Oppenheimer has correctly referred to "in wildly intemperate terms" the National Academy study. I think it is fair that the only study on which you refer, on which you base your testimony, also be subjected to some analysis, and we are going to request that that be done.

Mr. MANOWITZ. All right.

Senator MITCHELL. Now, I would like to ask you a further question. Have you ever heard of a proposed research plan called "Nonlinearity of Acid Precipitation Processes"?

Mr. MANOWITZ. A proposed research plan.

Senator MITCHELL. Yes.

Mr. MANOWITZ. Yes, sir; I am very familiar with that.

Senator MITCHELL. Very familiar with that, right. As I understand it, that is the plan that has been proposed to the Department of Energy for funding of $33 million to conduct research to establish the principle of nonlinearity in acid precipitation processes; is that correct?

Mr. MANOWITZ. No, sir.

Senator MITCHELL. It is not. Well, then you tell me what it is.

Mr. MANOWITZ. It is to try to obtain data to establish whether or not there is or is not linearity or nonlinearity in the processes that occur. Not to establish the principle of nonlinearity.

Senator MITCHELL. Well, the title of the study which I just quoted, and I will ask you again to tell me whether I have quoted it correctly, this is the title, "Nonlinearity of Acid Precipitation Processes."

Mr. MANOWITZ. That is the correct title.

Senator MITCHELL. That is the correct title.

Mr. MANOWITZ. That is correct.

Senator MITCHELL. Now, do I understand that the proposed researchers in that study are scientists from Argonne, Brookhaven, and Pacific Northwest Laboratory; is that true?

Mr. MANOWITZ. That is correct.

Senator MITCHELL. And the majority of the authors of the critical analyses of the National Academy study whose work you have presented here today come from Argonne, Brookhaven, and Pacific Northwest Laboratory; is that not correct?

Mr. MANOWITZ. That is also correct.

Senator MITCHELL. Now, if this report is accepted within the scientific community and the people of this country as establishing clearly the principle of linearity in acid precipitation processes in North America, there would be no need to do this study. Is that correct?

Mr. MANOWITZ. If the recommendations of the Academy report were followed, there would indeed be a need to accomplish this study.

The principal recommendation of the report is that more research is needed. So, I do not believe it was simply because the investigators at the National Laboratory happen to be interested in this particular area as a field of their own research that their comments were made that were critical but not, as I believe someone said, wildly intemperate.

As you will read the document yourself, I believe there are temperate statements made.

Senator MITCHELL. Well, all right. I am going to yield to Senator Moynihan in a minute. But I will just say, I have read in its entirety the review of—all it says—Reviewer E, and if that is not an unscientific, intemperate report, then I have not read one. I have spent much of my adult life in politics and so I have heard a lot of intemperate remarks.

In the first place, it begins with the sentence, "This review was written during a rushed 40-hour weekend." That is the first sentence of the report. Then it goes on to include a number of remarks which I will get into subsequently, and we will let the record judge as to whether these remarks can be described as scientific or intemperate, or something else.

But I now want to yield to Senator Moynihan. I have a number of other questions, Mr. Manowitz, and I will continue after Senator Moynihan has concluded.

Mr. MANOWITZ. Could I respond to that comment?

Senator MITCHELL. Yes, go ahead.

Mr. MANOWITZ. Unfortunately, when the reviews came in from the various scientists at the National Laboratory, I saw that they were indeed critical and appeared to me to be substantive.

What I did was to contact the Chairman of the Commission of the Academy, Dr. Herbert Friedman, and told him that I was getting a series of reviews that were critical and appeared to me to be substantive.

He asked me to send him those reviews. I will admit in hindsight that I mistakenly sent him the draft reviews as they first came in. One of those reviews was indeed intemperate in its language, I agree entirely.

What I have to say is that I personally have spent some 18 years as an editor of a technical journal and I have seen many an intemperate review. My own hide, perhaps, is a little bit thicker than it should have been in this particular regard and I should have realized how offensive the language was in that particular review and should not have circulated it.

I gave those documents very limited circulation because I am obliged, in my relationship to the Interagency Task Force, to report directly to the task force. The documents were not published by me.

The documents were published by Dr. Calvert who included them into the record.

I believe it was unfortunate that those initial documents—which as I say were draft documents—found their way into the record. I think you will find that the documents which I have submitted both to the House Committee on Science and Technology and to this committee are indeed both temperate and are the result of a review of the National Laboratory Directorate as well as a review of the individual scientists themselves.

Senator MITCHELL. Senator Moynihan, I yield to you. I have some more questions on this.

Senator MOYNIHAN. This is going to sound like an advertisement for myself but I assure you that it is not my purpose.

I am not a scientist but I have been a member of the President's Science Advisory Committee which was at that time the most, many say, singular institution in American science.

I have been a vice president, and a member of the Board of Directors of the American Association for the Advancement of Science, which is the largest organization of scientists in the world.

I am a member of the American Philosophical Society which is a scientifically oriented body in Philadelphia, founded by Benjamin Franklin, and a member of the American Academy of Arts and Sciences which was founded by John Adams.

I would like to say that I cannot in any way see that anything that Mr. Manowitz has said is other than normal science critique, normal resigned realization that whatever you know, you do not know enough and you need to know more and that no group of scientists associated with the national laboratories ever submits a research proposal in order to prove something to be true. You are not theologians, you are scientists and your proposal inevitably is, "let us see whether this is so," perhaps beginning with the hypothesis that it is so. Most good research begins with a hypothesis, does it not?

Mr. MANOWITZ. I believe so, sir.

Senator MOYNIHAN. And you say, "We are going to set out to see whether it is so," and then you make the point that it is, otherwise it would not be worth finding out something you are pretty sure is not so.

Your proposition is that the European data did not establish nonlinearity.

Mr. MANOWITZ. That is indeed my position.

Senator MOYNIHAN. That is what you think. And yet, you are also prepared to think that nonlinearity is a hypothesis which ought to be examined and can be.

Mr. MANOWITZ. As well as linearity.

Senator MOYNIHAN. Sir?

Mr. MANOWITZ. I said both nonlinearity and linearity are hypotheses that yet remain to be proven.

Senator MOYNIHAN. You consider the matter really just begun—I am going to be defensive about this. These are our people, you know; they are working for the Interagency Task Force which is the legislation we established and the laboratories are written into the legislation; are they not?

Mr. MANOWITZ. That is correct.

Senator MOYNIHAN. In the history of science, give us a feel for the first time this kind of proposition appeared. Gode, is it?

Mr. MANOWITZ. Gode, the German.

Senator MOYNIHAN. When did the first paper on this appear? I mean, 10 years ago, 20, 100?

Mr. MANOWITZ. Actually, in terms of atmospheric processes in the atmosphere, the chemistry of what occurs in the atmosphere has been studied very heavily over the last 25 years.

Senator MOYNIHAN. About 25 years. Well, that can be long as science goes, or not. But the particular nonlinearity of this particular process, a source-receptor in the particular chemicals, in the last 10 years you have been getting papers and measurements?

Mr. MANOWITZ. Actually, relatively few papers have come out.

Senator MOYNIHAN. Relatively few. The literature is just beginning.

Mr. MANOWITZ. is just beginning, and I believe the Academy indeed performed a service in accumulating quite a bit of that information and putting it into a single document.

Senator MOYNIHAN. Right. So, I mean, I want to ask all three of you. is it not normal science to come in with a proposition and have it criticized. and some people may get intemperate? You should see some of the comments on papers that are submitted to the American Political Science Review, they bring intemperance to the state of the art.

I mean, this is nothing but normal science work; is it not, gentlemen? Dr. Shannon, do you think that?

Dr. SHANNON. I agree.

Dr. OPPENHEIMER. It happens.

Senator MOYNIHAN. So, go ahead with your work, you are working for us. It obviously is very important to us if we can learn at the level of understanding of this committee which is very limited. There is not a scientist in the U.S. Senate, not one. There is not a single scientist in the Senate.

We are going to have to make major decisions and you are going to have to explain them to us, and you are going to have to reach some degree of consensus before we are going to have much confidence in what we do.

But I am right, am I not, in the thought that if you have a high constant of proportionality and it is linear, then you have a pretty good reason for saying, if you do something here, you will get something there. That is what we are trying to find out. That makes the case for some collective legislative action stronger than if you could not be confident of that. Is not that sort of what is at issue here?

Mr. MANOWITZ. Essentially, I agree with your statement.

Senator MOYNIHAN. Well, I would like to thank you all. I am not going to say anything intemperate about any of you.

We are absolutely dependent on you scientists to translate from language you know and we do not know; you are bilingual and we are not. That is very important and I just want to say that.

Thank you all.

Mr. MANOWITZ. Thank you, Senator.

Senator MOYNIHAN. I am going to have to leave in a moment, so I am going to leave you to this highly skilled Federal judge.

I would like to put in the record a small article from the New York Times of the arrangements that were being made for Mr. Ruckelshaus, our good friend, the Administrator of the Environmental Protection Agency, who had hoped to have an acid rain proposal ready from the administration by the end of September and indeed all arrangements were made for this to be announced in Canada and then, at the last moment, the White House evidently vetoed his proposal.

I think Senator Mitchell would agree with me that since we all heard privately from Mr. Ruckelshaus that he did hope to have something and he would proceed putting it forward, in part of these hearings we ought to ask him to come up and tell us what happened. Would you not agree?

Senator MITCHELL. Yes, I do, Senator. I agree. I think we should discuss it with the chairman at the earliest opportunity.

Senator MOYNIHAN. Thank you very much. Thank you, gentlemen.

[The article referred to follows:]

[From the New York Times, Oct. 20, 1983]

THE BEST LAID PLANS

William D. Ruckelshaus, the Administrator of the Environmental Protection Agency, had promised last summer that by the end of September he would produce a plan to curb acid rain.

So a plan was prepared and the agency was getting ready to unveil and promote it. Under discussion was an elaborate proposal called "draft of acid rain communications strategy." It included plans for speeches by Mr. Ruckelshaus, as well as the publication of numerous fact sheets and maps.

Arrangements were being made for satellite television feeds around the country and to Canada, on which falls much of the acid rain produced in the American Middle West. The Canadian Ambassador was to be briefed. There were plans for Mr. Ruckelshaus to be available to CBS and ABC the night of the announcement and to NBC the next morning.

Everything and everybody at E.P.A. was ready. Then Mr. Ruckelshaus went to the White House, a week ago Wednesday, to discuss his plan. There he learned that it was unacceptable to several high-level officials. Now there is nothing to announce, no communications strategy to implement and nothing to sell to the Canadian Ambassador, except possibly an umbrella.

Senator MITCHELL. Thank you, Senator.

First, let me say that the record will be kept open to permit Dr. Calvert to submit any further response that he wishes to the comments made here today regarding the National Academy study. (See p. 559.)

Dr. Shannon, you will recall that you testified before this committee last year.

Dr. SHANNON. Yes, sir.

Senator MITCHELL. And you will recall that I asked you a series of questions regarding precisely the subject matter that is now being discussed in this committee; do you recall that?

Dr. SHANNON. Yes, sir.

Senator MITCHELL. Since we have the record at the time and having read the record, I took your testimony to mean that you were generally in agreement with the proposition that there is linearity as between emissions and depositions in North America. Do you consider that to be a fair assessment of the testimony you gave before this committee last year?

Dr. SHANNON. I would probably qualify that to the extent that I talked about a seasonal or annual average, that it is my belief—I have not proved it—that the long-term source/receptor relationship is essentially linear.

Senator MITCHELL. And I want to ask whether you were present earlier this year among a group of scientists who met with Administrator Ruckelshaus to discuss the acid rain issue.

Dr. SHANNON. Yes, Senator, I was.

Senator MITCHELL. I was not present, so I must rely upon the information that has been provided to me by others. But it is my understanding that this occurred on July 20 of this year.

Dr. SHANNON. I have no certain memory but that sounds right.

Senator MITCHELL. I also understand that 6 days later, on July 26, Mr. Manowitz wrote to officials of the Academy, enclosing a copy of your review of the Academy report. Do you recall that?

Dr. SHANNON. I will take your word on the dates. It sounds like a reasonably chronology.

Senator MITCHELL. So that at the time that you participated in the meeting with Administrator Ruckelshaus you were either working on or had completed your report; is that correct?

Dr. SHANNON. That is correct, Senator.

Senator MITCHELL. Now, I am advised that Dr. Kasper, who testified here earlier today, presided at the meeting and explained the Academy's findings. I now quote from the record of that meeting. He said,

> The recent report concluded that averaged over a long time, they said about a year, and averaged over a large area, they said something like Eastern North America, there was no significant nonlinearity in the relationship between emissions and deposition. And, if this is so, one can anticipate that reductions in emissions of precursor gases will result in proportional reduction in both wet and dry depositions.

Following that, Dr. Kasper asked whether there is any significant disagreement with that conclusion of the report. The record reflects that it was greeted by silence which he then said he took to mean agreement by all of those present with that conclusion of the report.

Do you recall the statements I have just read?

Dr. SHANNON. Yes, sir, to the best of my memory, that is what happened.

Senator MITCHELL. Do you recall being present during that meeting?

Dr. SHANNON. Yes, Senator, I was.

Senator MITCHELL. And do you recall remaining silent when Dr. Kasper asked that question?

Dr. SHANNON. Yes, Senator. I also recall how he had particularly qualified the statement.

Senator MITCHELL. As I just read it.

Dr. SHANNON. Yes, Senator.

Senator MITCHELL. Right. You expressed no disagreement with it at that time.

Dr. SHANNON. No, Senator, I did not.

Senator MITCHELL. Now, you have used linearity in your models; have you not?

Dr. SHANNON. Yes, Senator, and I continue to do so.

Senator MITCHELL. Do you now have any reason to believe that your models are therefore inaccurate, for that reason?

Dr. SHANNON. I can demonstrate that my model can reproduce both the annual wet deposition of sulfate and the annual wet deposition of nitrate in all the major observation networks in the United States and

Canada to a correlation of about 0.85 in either case. That is the combined effect of all sources and is neither proof nor disproof of how well models can do in evaluating the effect of a single source.

Senator MITCHELL. And you stated in your statement here today, "In general, I have far more agreement than disagreement with the NRC committee." Is that correct?

Dr. SHANNON. That is correct.

Senator MITCHELL. That is in your written statement here today. You did not say that orally, but I wanted to assert that it was.

Mr. Manowitz, we referred earlier to a reviewer's comments which I gather you agreed were intemperate in the earlier version. I thought it was interesting that in the earlier version the reviewer made this statement:

> I was asked to review this report. No one asked my opinion about the issue but I would like to add it. I do not disagree with the general implications of this report. If depositions are to be reduced, then it seems more reasonable to decrease emissions than to increase them. My disagreement is with the details in this report.

Was that included in the edited version that you presented to this committee today?

Mr. MANOWITZ. That particular statement was not included.

Senator MITCHELL. Was not included.

Dr. Oppenheimer, I would like to ask you. You made what I thought was a rather flat and emphatic statement and I just want to make certain I heard you correctly. You said that, "No one has presented any evidence anywhere, at any time, to establish the principle of nonlinearity in acid precipitation processes in North America." Is that what you said?

Dr. OPPENHEIMER. Yes; and I am referring in particular to the peer reviewed literature. Of course, people say things anywhere, at any time and people have said and proposed evidence for nonlinearity. You know, you can get people to say anything that they want to say.

But in the peer reviewed literature in the context of having to go through the scientific review process, the evidence does not exist. It simply does not exist, has never been presented.

Again, we are referring to averaging over reasonable time scales and reasonable distances. The microscopic processes may be nonlinear occasionally in some context. But over reasonable distances and time in the peer reviewed literature there is no evidence anywhere, that I know of. Even the European data has not been interpreted in the peer reviewed literature in any thorough, significant way to indicate nonlinearity.

Senator MITCHELL. Mr. Manowitz, what is the status of your proposed research program to which I referred earlier?

Mr. MANOWITZ. My understanding is that the Department of Energy is considering funding that program in fiscal year 1985.

Senator MITCHELL. When do you expect a decision to be made?

Mr. MANOWITZ. Hopefully, within the next several months.

Senator MITCHELL. Can you tell me what period of time it is expected that that study will take place?

Mr. MANOWITZ. The proposal is for a study over a 5-year time period.

Senator MITCHELL. Over a 5-year time period?

Mr. **Manowitz**. That is correct.

Senator **Mitchell**. If it is funded in fiscal year 1985, when does that mean you will begin in terms of actual calendar dates?

Mr. **Manowitz**. If it is funded at the beginning of fiscal 1985, that implies October 1, 1984.

Senator **Mitchell**. I have other questions but in view of the lateness of time and the fact that we have other witnesses who have come here from some distance, I will reserve and submit them in writing to you gentlemen.

Thank you all very much for your testimony here today.

The final panel includes Dr. Richard Klein and Dr. Richard Wright. Proceed, please, in whatever order you choose. I ask that you make a summary of your statement.

Actually, you gentlemen have relatively shorter statements than others, we will hear both of them and then have some questions.

STATEMENT OF RICHARD KLEIN, PROFESSOR, DEPARTMENT OF BOTANY, UNIVERSITY OF VERMONT

Dr. **Klein**. My name is Richard Klein. I am professor of botany at the University of Vermont, and I am codirector of the acid deposition program. Our research is supported by the R. K. and A. W. Mellon Foundation, the Texaco Foundation, the Jackson Hole Foundation, plus Federal funds. For 3 years prior to September 1983, we received funding from the American Electric Power Service Corp.

Independently of sources, transport or transformation, present depositions in New England are acidic with average weighted pH values of 4.1—at least 10 times more acidic than nonanthropogenic precipitations. Some precipitation events are up to 50 times more acidic.

Acidic rain and snow contain significant amounts of metals including cadmium, copper, lead, and zinc which have accumulated in the soils. Highly acidic snowmelt is 10 times more acidic than the bulk snow. Snowmelt and precipitation solubilizes indigenous soil aluminum and deposited heavy metals that then enter the soil water solution and can adversely affect plant development.

Above 2,200 feet elevation, cloud water, which is five times more acidic than rain and contains higher concentrations of metal, condenses on the foliage and hence the acid and metal loading at higher elevations is much greater than at lower elevations. These are very well documented facts.

Our field research started in 1965 and we now possess the best field data base in North America for high elevation forests. Complete floristic and climatic studies in 1965, 1979, and 1983 have been statistically compared. Briefly, Senator, our major study area, Camels Hump Mountain in Vermont, plus other Vermont mountains are disaster areas.

You will find on the last page of my formal submission a table which I would like to refer to rather briefly.

Yes. This is what Camel's Hump looks like as of the early summer of this year. All of the gray material you see are dead trees. These trees were alive in 1965 and a fair proportion of them were alive in 1979. They are now dead.

As seen on this table which I am presenting at this point, we have been able to measure quantitatively the number of plants that are alive and an estimate, based on standard procedures, of what we call the biomass, the total amount of living material in the forest. We divided it up by species, as you can see here.

Between 1965 and 1983, the amount of tree material of sugar maple dropped by 25 percent. That of beech by 25 percent. That of red spruce by 71 percent. That of balsam fir by 19 percent. This point on balsam fir is very instructive.

We have found that between 1965 and 1979 there was no significant decrease in the health, status, and growth of balsam fir. Between 1979 to 1983, there has been a 20-percent decrease in the number of living trees of balsam fir.

We have been able to document the decline not only with the trees that are large, but we have found that the seedlings of many of these species simply no longer exist on the forest floor. In short, the forests are deteriorating at a very rapid rate and their capacity to replace themselves is now, we believe, quite limited.

The obvious question that we have to deal with is whether there is a cause-and-effect relationship among the meteorological facts of acidic deposition, the facts on alterations in the composition and quality of the nutritive soil solution and facts that I have just presented on the destruction of the northern coniferous and hardwood forests in the mountains of New England and elsewhere throughout North America and the world.

Our studies have shown that there are series of particular characteristics of the severely impacted ecosystems in the Northeast. They are usually on westerly facing slopes, have very shallow, acidic soils, and are low in nutrients with high levels of organic matter.

These are very harsh environments. There are periods of drought, excess water, wide variations in temperature, and high winds. Trees are continually under stress, and it is a situation wherein additional stress, such as that imposed by acidic deposition, becomes too much to bear.

Concomitant with our field studies, we are conducting laboratory experiments in which we attempt to simulate one ecological factor at a time and evaluate the possibility of whether this stress—whether it is acid, metals, et cetera—can be a contributing factor to the declines that we have observed.

Briefly, and to summarize a great deal of work, acid loads and metal concentrations that mimic natural conditions repress the activity of the soil organisms that cause the decomposition of litter and the release of nutrients needed for forest plants.

Litter has doubled in the last 20 years, which may prevent tree seedlings from becoming established. This is called the smothering effect.

Acidic depositions leach nutrients from this litter and move it away from the ecosystem so that the plant is no longer supplied with adequate levels of nutrients.

Acid and metals decrease the growth of mosses and can account for the loss of the moss coverage on the forest floor. Since 1965, there has been a decrease in the coverage of the forest floor by mosses by over 50 percent in all of the ecosystems.

The acids and metals can significantly reduce the ability of red spruce and balsam fir to take up and move water and nutrients through the plants.

Acids and metals in hydroponic cultures can kill the plants with the observed sequence of death mimicking with some precision the sequence we have observed in the field.

Acids and metals can reduce the growth of the root systems of seedling plants and can cause death of the seedlings, and we have field measurements that show in the paucity seedling.

We can leach nutrients including proteins, amino acids and sugars from leaves with acidic deposition which may cause the loss of the ability of the plant to use nutrients to continue its growth.

We have evidence that those fungi that normally are associated with the roots of plants and are involved in the uptake of water and nutrients by the trees are not to be found on the mountains and, in addition to that, artificial simulations have indicated that acids and corresponding increases in soluble metals can suppress the growth of these fungi.

We have found that metal ions which have been solubilized from indigenous and deposited metals by acidic depositions and acidic snowmelt are accumulating in the rings of sugar maple and red spruce. This allows us to use these as a marker to determine when widely dispersed acidic deposition reached the mountains of Vermont. We found that the critical period is 1940–50, as has been suggested by a large number of other studies. We are doing dendrochronological studies in which we are evaluating the possibility that the growth vigor in the surviving trees has been decreased. This work is still underway.

We are evaluating the possibility that the observed and measured alterations in mountainous ecosystems may be due to causes other than to acidic deposition. Disease and insect damage are very unlikely to be directly involved. The evidence has tended to rule out drought as a major causal factor, although drought is certainly a stress that, combined with other stresses, becomes a factor in the destabilization of ecosystems.

We and others discount drought—which has been discussed in considerable detail in recent months—as a primary cause of ecosystem failure on several solid ecophysiological grounds.

One, we have been able to measure in the tree rings themselves the effects of droughts that occurred sporadically over a long period of time, 150 years and more, using the balsam fir and red spruce on our mountains. In every instance where there has been a drought signal in the wood, the trees survived and rebounded. The one exception to this is the present situation where the trees are not rebounding: They are dying.

The syndrome observed in tree decline and death is now occurring in young trees that were not even present in the forests during the period of the presumed droughts; that is, these are young trees, trees that were established after the period of time when the presumed droughts were supposed to have occurred.

We have solid evidence, based upon 1965 work, that on Camel's Hump and the other upper elevation mountains in New York State and New England, as well as farther south in Appalachia, the upper elevations are receiving large amounts of cloud water and they were not dry during this period at all. Weather station reports of precipitation are usually obtained at airports, which are low elevation stations, and they do not reflect the water patterns that exists in mountainous areas.

Quantitative soil moistures may, during that 1960's, indicate that these forests were not dry and that the declines that we are observing were not due to drought.

If the weather person tells you on the evening news that there is a 10-percent chance of rain, it is very unlikely that you will carry an umbrella. But if you hear that there is a 90-percent chance, more properly a 90-percent probability of rain, you will wear a raincoat and you will carry an umbrella.

In acid deposition studies we, too, must deal in probabilities, since absolute proof in the legal or even in the scientific sense is unlikely ever to be obtained.

Based on our studies, those of meteorologists, soil scientists, terrestrial plant ecologists, and physiologists throughout the world, there is a high probability that acidic depositions are the primary and proximate cause of the destabilization and destruction of terrestrial forests and ecosystems, of mountainous areas in New England and elsewhere. We have not been able to provide an alternative explanation that is consistent with all of the available facts.

We are quite aware that there is not, now, unequivocal proof for the contention of an acid-metal causation of forest damage. Additional research will narrow the gaps in our knowledge, but it will never be fully adequate simply because of the complexity of terrestrial ecosystems and the complete absence of a control area in North America that is not receiving acidic depositions.

We believe that the evidence is sufficiently compelling and the probability of cause and effect is sufficiently high to warrant legislation designed to reduce significantly the production of acidic and metal-containing pollutions. Based on our research as well as the research of others, and on very solid ecological and physiological grounds, we believe that significant reductions in acidity and metal content of both wet and dry depositions will lessen the stresses that are now literally destroying forested, mountainous ecosystems. Even if such reductions were to be implemented immediately, it is very likely that some of the damage to forests may be irreversible.

Thank you.

Senator MITCHELL. Thank you very much, Dr. Klein. Dr. Wright?

STATEMENT OF RICHARD WRICHT, PROFESSOR, DEPARTMENT OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VIRGINIA

Dr. WRIGHT. Thank you, Senator.

My name is Richard Wright. I am from the Norweigian Institute of Water Research in Olso, Norway. I am currently on leave at the University of Virginia, Department of Environmental Sciences.

So, it is a rare opportunity that I am in the United States to be here with you today.

I have a few viewgraphs I would like to show you, if I may.

This map should be familiar to you by now. I would like to show three things. First of all, you will see it is a map of North America and the line labeled pH 4.6 is the line inside of which precipitation is more acidic than pH 4.6. The farther you get into that area, the more acidic is the precipitation.

The second thing I would like to show you is the hatched area. Those are on a large-scale areas which are sensitive to acid deposition, in other words, the fresh waters, the streams and lakes and ground waters in those areas are sensitive to acid deposition.

The final thing are the numbers and letters. The numbers inside of the pH 4.6 isoline are areas in which acidified lakes and streams have been reported in the literature and the letters outside—most of them are to the west—are reference areas. These are comparable areas not receiving acid rain in which the waters are not acidified.

I present this, I think this is old information, to you but I will be coming back to that at the very end.

There is a close relationship between the sulfate concentration in lakes and the sulfate concentration in precipitation. The more sulfate in the rain, the more sulfate in the lakes, and the more likelihood, as you go up in the sulfate in the lakes, that these lakes will be acidified and have a low pH.

These are data compiled last year from 15 separate areas in North America. The Rocky Mountain National Park is an area not receiving acid rain, and here we have the Adirondacks.

The sulfate level goes up in lakes and, if we are in a sensitive area, the chances are we will get low pH and we will get high concentrations of aluminum in the stream and lake water. This area up here is toxic to fish, just to use one group of organisms.

There is good evidence that fish populations have declined in various regions of North America. Here is a recent example from salmon rivers in Nova Scotia. These rivers are all acidic today. You will see that the salmon catch in these rivers has declined dramatically in the last 30 to 40 years.

The salmon and trout lost in acidified lakes is really only the tip of the iceberg. The impact of acid rain and acidification of the fresh waters affects every major group of organisms in the lake and thereby every major process within the lake.

You will see here, as the pH goes down from 7, or 6 or 5 which may be a normal pH, down to below 5, we lose a large number of species, that is a large number of types of organisms in every class found in the aquatic environment.

Now, this story which I believe is old and well established in the literature about acid rain causing acidification of lakes and streams has been challenged recently in the literature by, primarily, soil scientists. Their argument runs that because soils in these areas are naturally acidic and have a very large store of natural acids and indeed a very large annual production of acid, that the little bit of acid coming in acid rain certainly cannot be the cause of the acidification. In other words, cannot be the cause of this major environmental change that we have seen in both North America and Europe.

Their explanation for, then, the cause of the environmental change is that the land use in these areas has changed. That is, there has been logging; there has been abandonment of farms, or such other such land use that the vegetation has changed, such that the soil has changed and therefore the soils have become more acidic, and therefore the stream and lake water has become acidified.

Now, to counter that argument, I believe there are many lines of evidence one can bring to bear, the first of which is to go back right to our original map. Indeed, we see that although we find acidified lakes and streams within the area receiving acid rain, in comparable areas outside of that area no such waters have been reported.

Indeed, we can find areas, for example, in northern Minnesota, with abundant land use changes such as logging and forest fires, and those have ecological changes in the waters. But those changes do not include acidification.

So, the first argument is that the land use change, one counter argument, does not explain the empirical data and it does not explain it in time, either. This is a very recent work on Big Moose Lake in the Adirondacks where the pH history of the lake has been reconstructed by studying the fossil diatoms preserved in the lake sediment. Every year, a new layer of lake sediment is laid down in the bottom and by studying the sediments, the historical record preserved in the sediments, one can reconstruct what the pH of that lake must have been. We find that for this study where the record goes back to about 1800, we have a pH between 5.5 and 6 which is normal for these sensitive lakes in the Adirondacks, or in northern Minnesota, or in the Cascade Mountains of Oregon. In spite of development and logging, and forest fires several times, there was no major change in the acidity of this lake until about 1950, at which time it decreased dramatically.

Now, we have just heard from Dr. Klein's testimony that indeed the 1950's he recognizes as about the period of time where environmental changes have occurred in nearby Vermont. And we know this picture here would fit the time picture on the acidity of precipitation.

So, how do we explain the fact that all of these acid soils do not cause the acid stream water and lake water, what is the explanation?

The explanation is that you simply cannot remove the acid out of the soil without a vehicle to do so, and the sulfate provides you with that vehicle. I will see if I can explain this. There are two parallel sites, one is in Petersburg, Alaska—there is no acid rain, the pH of the rain is 5.4. There is very little acid in the rain. The soils are very acidic, pH 4 in the soil and, as you go down in the soil, the pH goes up somewhat, and the pH of stream water is 6.4 with very little sulfate.

So, here we have a situation with a very acid soil but because the rain is not acid, neither is the stream water.

Here I have chosen an example from Norway—it could have been somewhere in the Adirondack Mountains, for that matter—where we have very acid rain, pH 4.2; lots of sulfate in the rain, of course. We also have acid soils and because the sulfate can transport the acid out of the soil, we have acid stream water, pH 4.5 and we have lots of aluminum, dissolved aluminum. The combination of the acid and the aluminum kills the fish.

That is all the vu-graphs. I would just like to conclude with one final statement.

Just as we have heard testimony today about the linearity and nonlinearity of atmospheric transport, you can see that there are instances where the scientific community does not 100 percent agree on what happens at the receptor sites, what happens on the effects both in the terrestrial and the aquatic.

I do not believe that we will ever achieve complete agreement among all the scientists working in this field. In fact, it is difficult to set up a hypothesis that will, or set up an experiment, that will give you the proof.

If I might just end by quoting the scientist Carl Sagan, "There are some problems where inferential evidence is all that we will ever have. Once the catastrophe arises, it is too late to deal with it."

Senator MITCHELL. Thank you, Dr. Wright. Your statement is one of the strongest I have seen on the links between acid deposition and damage to water resources. How long have you worked in this field?

Dr. WRIGHT. I have been working in this field for about 8 years. The majority has been in Scandinavia.

Senator MITCHELL. Based on your knowledge and experience, do you believe there is any valid hypothesis other than acid deposition that explains the lake and stream damages which are now being seen in North America and Europe?

Dr. WRIGHT. The answer is, no, with a small conditional. And that is that someone will always find an exception. But I would say in 90 percent or 95 percent of the cases there is no other valid explanation I am aware of.

Now, one other thing that I might say here, that this does not exclude that land use changes in concert with acid rain may not cause acidification of the fresh water. But land use change by itself apparently does not do so.

Senator MITCHELL. And I understand, Dr. Klein—you dealt with this in an affirmative way in your statement—you have considered other hypotheses and you stated you have not been able to provide an alternate explanation that is consistent with all the available facts regarding damage to forest systems.

Dr. KLEIN. Right.

Senator MITCHELL. Well, I thank you both very much for very valuable testimony that will add a great deal to the record and establish, I think, the continuing problem of damage that is resulting from acid deposition. As you heard from the earlier testimony, there is no unanimity about what should be done to deal with it. But I think the evidence of the damage is clear and indisputable, and you have helped us to understand that.

So, I thank you both very much.

These are the last witnesses, so the hearing is concluded.

[Whereupon, at 1:45 p.m., the committee adjourned, to reconvene subject to the call of the Chair.]

[Statements and other material supplied for the record follow:]

Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries

[Note: The following are excerpts from the above named report. The report, in its entirety, has been retained in committee files.]

This report was prepared by the Energy Information Administration, the independent statistical and analytical agency within the Department of Energy. The information contained herein should not be construed as advocating or necessarily reflecting any policy position of the Department of Energy or any other organization.

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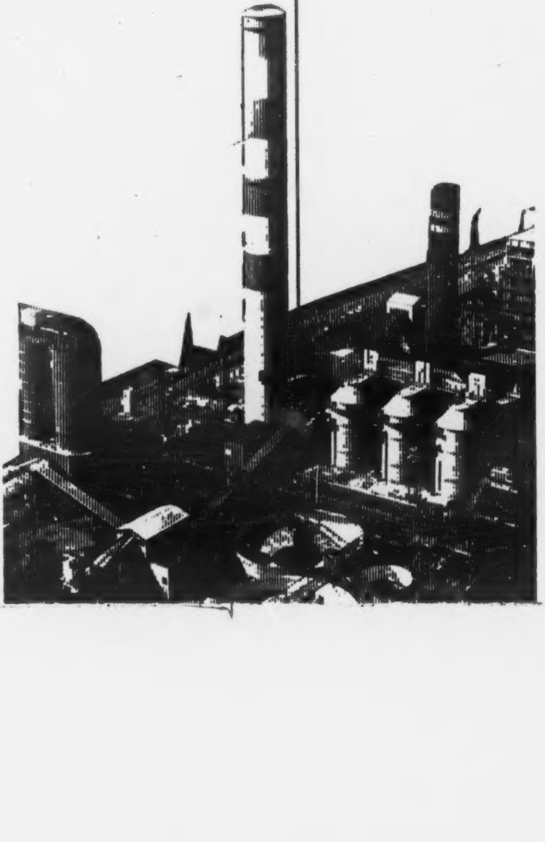


EXECUTIVE SUMMARY

Senate bill S.3041, the "Clean Air Act Amendments of 1982," addresses the problem of acid deposition (acid rain) in the eastern United States. This legislation proposed reducing the sulfur dioxide (SO_2) emissions and limiting the nitrogen oxide (NO_x) emissions in a region that includes the 26 States east of the Mississippi River, and 5 States adjacent and to the west of the Mississippi, plus the District of Columbia, subsequently referred to as the 31 States. Under the proposal, by 1995 this region must lower annual SO_2 emissions to 8 million tons less than actual emissions in 1980, a reduction of approximately 50 percent of electric utility emissions in 1980. Increases in SO_2 emissions after January 1, 1981 must be offset by reductions from other sources.

Acid rain refers to the wet and dry deposition of acids--chiefly sulfuric and nitric acids--from the atmosphere to the earth's surface. Acid rain occurs after SO_2 and NO_x emissions combine in the atmosphere with other materials, in a chemical reaction. Thus the emission of SO_2 and NO_x is a precursory condition to the formation of acid rain. SO_2 and NO_x emissions into the atmosphere come from both natural and man-made sources.

This study determines the lowest cost means by which electric utilities can reduce their 1995 SO_2 emissions to comply with the legislation. Fundamental scientific and economic uncertainties surround the potential environmental benefits that would result from this level of reduction in SO_2 emissions. Therefore, a cost-benefit analysis of the proposed legislation is not currently possible.

This report is to help legislators, policymakers, and industry analysts to assess the costs of Senate bill S.3041--as well as costs of future similar legislation that may be proposed--to the electric utility industry and its consumers, and to assess its impact on the coal industry. Senate bill S.3041 did not pass the 97th Congress, but similar bills have been introduced in the 98th Congress, such as S.768. This report is unique in two respects:

- Every utility coal-fired boiler and electrostatic precipitator in the 31 States specified in the proposed amendment was examined to determine how the utility could reduce its SO_2 emissions. Limitations on the utility's options were taken into account, so that utilities' responses to the proposed amendment could be analyzed.
- Demand levels for electricity and transportation rates for shipping coal were varied in order to determine how such variations of these two important parameters would affect the projected results.

"Base case" in this study is actually a pair of base cases, both of which are examined for their effects on scenarios relating to the electric utility industry and to coal production. In one base case, S.3041 is assumed to be in effect; in the other base case, it is not.

Both base cases rest on the same two assumptions. The first assumption, drawn from the mid-case projections of EIA's 1981 Annual Report to Congress, is that the average annual growth in demand for electricity is 2.9 percent from 1980 through 1995. The second assumption, also based on EIA projections, is that transportation rates for coal will rise at a real average annual rate of 3 percent from 1983 through 1995.

It is assumed that decisions are made over a sufficiently long lead time to permit market structures to adjust in an orderly manner. For example, railroad facilities are assumed to be available when required, new western coal mines opened as needed, and long-term coal contracts (such as existing contracts with coal mines located near power plants) renegotiated when necessary. Mine-mouth power plants using high-sulfur coal are assumed to be able to switch to lower sulfur coal by 1995; however, captive coal mines associated with mine-mouth power plants in Ohio and Pennsylvania are projected to continue burning medium- and high-sulfur coal. These States include more than 82 percent of the total captive mine capacity included in this legislation.

The sensitivity cases examined the range of possible outcomes due to changes in two key assumptions. The growth in demand for electricity is varied to a high of 3.9 percent, and to a low of 1.9 percent. Growth in demand for electricity is studied because it affects the ability of a utility to retire plants that burn high-sulfur coal, or to use them less. It also affects the increase in SO_2 emissions from new sources that must be offset by existing plants.

Two variations of transportation rates are studied because of uncertainty about the additional increases required to obtain revenue adequacy for the railroads. Revenue adequacy refers to the ability of a railroad to earn enough profit to attract new capital. In one variation, the transportation rates increase 5 percent over the base case, compounded annually, and in the other, 9 percent compounded annually. Future rail rates for transporting coal affect demand for low-sulfur coal mined in the West.

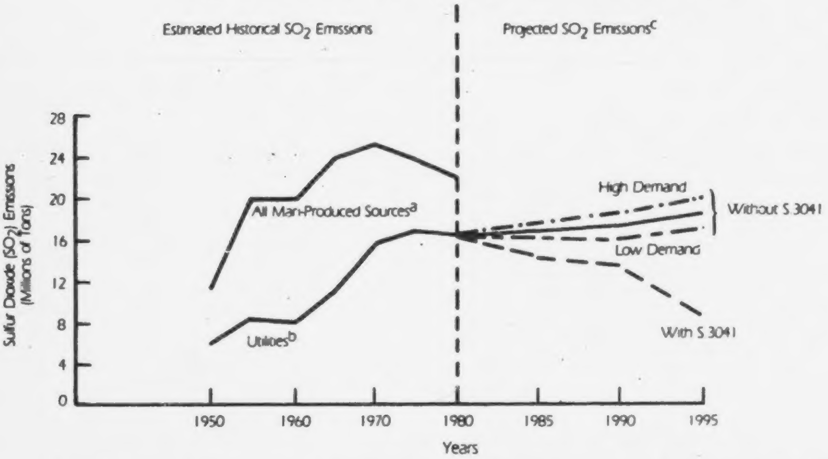
The report projects the amount of emissions from electric utility power plants that would occur by 1995 under the current limitations of the Clean Air Act. It also analyzes the effects of the proposed legislation on the electric utility industry, including the capital expenditures required to reduce SO_2 emissions, and the resulting effects on the cost of electricity. The initial 8-million-ton reduction in SO_2 emissions is assumed to be accomplished solely by electric utilities; industrial emission reductions are not considered. Similarly, only increases in SO_2 emissions from power plants are assumed to be offset by reductions within the utility industry; increases and offsets of industrial emissions are not addressed. Effects on the coal industry are also examined. The report concludes with a general discussion, based on current literature, of the potential benefits to be gained from reductions in SO_2 emissions. The benefits from the proposed legislation of an 8-million-ton reduction in SO_2 emissions and the value of such benefits are not specifically addressed.

The results developed in this study assume an economic response by electric utilities in meeting the requirements of the legislation. The analysis uses a modeling framework that minimizes the marginal cost of producing electricity on a regional basis, subject to the constraints of lower SO_2 emissions. Although uncertainties regarding some assumptions in this study have been analyzed, there are technical (e.g., railroad congestion), financial (e.g., cost of capital), and political (e.g., new legislation) considerations not addressed here. These considerations could lead to lower cost impacts or, more likely, higher costs than those reported. For example, if new legislation restricted utilities to the use of high-sulfur coal, then more retrofits with scrubbers would be required and costs would be higher.

Projections

Without the enactment of S.3041, SO_2 emissions from power plants are projected to increase for the 31 States from 16.1 million tons in 1980 to 18.1 million tons in 1995 (see Figure ES1). During the same period, NO_x emissions are projected to

Figure ES1. Electric Utility SO_2 Emissions in 31 States



[a] United States-Canada Memorandum of Intent on Transboundary Air Pollution, "Emissions, Costs and Engineering Assessment," United States/Canada Work Group on Emissions, Costs and Engineering Assessment, Work Group 3B, Final Report, June 1982, Table B.1 3, pp. 36-37

[b] Pacific Environmental Services, Inc., Durham, N.C., estimated from electric utilities reports filed with the Energy Information Administration and the Federal Power Commission.

[c] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983

increase from 4.8 million tons to 6.3 million tons. This increase will occur because new sources of emissions will be added more rapidly than old power plants are retired. The emission levels increase through 1995 even though the new coal-fired units produce much lower emissions as they generate electricity. Emissions from existing coal-fired units will decline continually as these units retire. The proposed legislation would accelerate this decline by requiring these units to reduce the 1980 SO_2 emissions level by 8 million tons in 1995 and to offset new emission sources. When these existing units are all retired, 30 to 50 years after 1995, emission levels will be approximately the same with this legislation or without it. A limitation of this study is the absence of quantitative results for the post-1995 period.

Electric utilities can reduce their SO_2 emissions from existing power plants by (1) retiring older units and/or reducing their use, (2) burning lower-sulfur coal, and (3) retrofitting existing power plants with flue gas desulfurization (FGD) systems. Each option has its own costs.

The impacts of S.3041 in the 31 States are summarized in Table ES1 for 1995. This table displays the projected values for each case with S.3041 minus those projected without S.3041 in order to determine the impacts of the proposed legislation. The increase projected in cumulative capital expenditures by 1995 is comprised of the costs to retrofit units with FGD systems, to modify some boilers or electrostatic

Table ES1. Differences in Expenditures and Capacity Modifications Projected with S.3041, Minus Those Projected Without S.3041, for the Base and Sensitivity Assumptions in 31 States, 1995

Impact of Legislation	Base[a]	Transportation Cost 5%[b]	Transportation Cost 9%[c]	Electricity Demand Low[d]	Electricity Demand High[e]
Financial					
Incremental Cumulative Capital Expenditures					
(Billion 1980 Dollars)	8.6	10.1	11.1	7.2	17.8
(Billion 1982 Dollars)	10.0	11.7	12.9	8.4	20.6
Incremental 1995 Annual Costs: Fuel, O&M					
(Billion 1980 Dollars)	2.6	4.1	4.6	0.6	6.7
(Billion 1982 Dollars)	3.0	4.8	5.3	0.7	7.8
Increase in 1995 Electricity Prices					
(1980 Mills per Kilowatthour)	2.7	3.0	3.0	0.9	3.7
(1982 Mills per Kilowatthour)	3.1	3.5	3.5	1.0	4.3
Incremental 1995 Revenue Requirements					
(Billion 1980 Dollars)	5.9	6.7	6.7	1.7	9.6
(Billion 1982 Dollars)	6.8	7.8	7.8	2.0	11.1
Operational					
Capacity Retrofitted with FGD					
(Gigawatts)	21.8	34.8	42.4	10.7	42.9
Capacity Converting to Low-Sulfur Coal					
(Gigawatts)	99.1	71.4	65.8	75.2	95.6

[a] The base case has a 2.9 percent average annual rate of growth in demand for electricity and approximately 3 percent average annual real increase in rail transportation costs. This column contains the difference in the base case with S.3041 minus the base case without S.3041.

[b] The 5-percent increase (compounded annually) in transportation costs is in addition to the 3 percent real increase in the base case. This column contains the difference in the 5-percent case with S.3041 minus the 5-percent case without S.3041.

[c] The 9-percent increase (compounded annually) in transportation costs is in addition to the base case transportation rate. This column contains the difference in the 9-percent case with S.3041 minus the 9-percent case without S.3041.

[d] Low demand is a 1-percent decrease (1.9 percent average annual growth rate from 1980 to 1995) in electricity demand growth. This column contains the difference in the low demand case with S.3041 minus the low demand case without S.3041.

[e] High demand is a 1-percent increase (3.9 percent average annual growth rate from 1980 to 1995) in electricity demand growth. This column contains the difference in the high demand case with S.3041 minus the high demand case without S.3041.

precipitators to burn low-sulfur coal, and to build additional power plants or transmission lines in order to retire older units or reduce their use. In the base case with S.3041, capital costs increase by $8.6 billion (1980 dollars). Of this total, FGD costs in 1995 are projected to be $2.8 billion (1980 dollars) higher than in the base case without the legislation; the cost to modify boilers or electrostatic precipitators is projected to increase by $2.1 billion (1980 dollars); and expenditures for new plants and transmission lines are projected to increase by $3.7 billion more than without S.3041 (1980 dollars).

In addition to increased capital expenditures, there would also be increases in the operation and maintenance expenses and fuel expenses for electric utilities in 1995. The expenditures for operation and maintenance are expected to increase by $335 million and for fuel by $2.3 billion (1980 dollars) if such legislation is implemented.

Increases in the price of electricity to consumers caused by the required reductions in SO_2 emissions are also projected. The price increases begin primarily after 1990 as significant capital expenditures are made, and in 1995 they are projected to be 2.7 mills per kilowatthour (1980 dollars) higher in real terms in the base case with S.3041 than without S.3041. This price increase is the result of an additional revenue requirement of $5.9 billion (1980 dollars; $6.8 billion in 1982 dollars) in 1995. This analysis assumes a time-phased plan for compliance with the legislation. The 1995 annual revenue requirement could be as high as $9.6 billion (1980 dollars; $11.1 billion in 1982 dollars), as shown in Table ES1. The results of this analysis fall within the range of those reported by other investigators. A detailed comparison with other studies is included in Chapter 7.

Findings

The changes proposed by the Clean Air Act Amendments of 1982 would result in a reduction of over 50 percent in the amount of SO_2 projected to be emitted by electric utilities in the 31 States in 1995. This represents only a 20-percent reduction in the 1980 natural and man-produced SO_2 and NO_x emissions, which are precursors of acid rain.[1]

Major findings of this report assessing the impacts of the proposed legislation using a least-cost approach are summarized below:

- Switching to low-sulfur coal is projected to be the preferred choice of electric utilities to reduce SO_2 emissions. Capital expenditures are not required for 60 percent of the boilers that convert to low-sulfur coal. However, if transportation rates for shipping coal increase substantially, utilities in the Midwest would likely continue using high-sulfur coal produced in their own or nearby States, and would retrofit more power plants with an FGD system.
- Cumulative capital expenditures in the 31 States affected by the proposed legislation are projected to increase by $7.2 billion to $17.8 billion, in 1980 dollars, for the range of scenarios considered. Most of this increase

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[1] Appendix B. Also, Jennifer A. Logan, "Nitrogen Oxides in the Troposphere: Global and Regional Budgets," Center for Earth and Planetary Physics (Harvard University, December 1982), Table 10. (Submitted for publication to Journal of Geophysical Research.)

occurs from 1991 through 1995 and represents 4.4 to 9.6 percent of projected total capital expenditures by all utilities in the 31 States for that period.

- Average electricity prices are projected to increase by 0.9 to 3.7 mills per kilowatthour across the various scenarios in 1995, as utilities must recover higher capital expenditures, fuel expenditures, and operating and maintenance costs. The 1982 average retail electricity price for privately owned utilities was 52.8 mills per kilowatthour in 1980 dollars.[2]

- The coal industry is likely to experience large shifts in the amount of coal produced in the different regions. In the Midwest, coal production is projected to drop below its 1980 level, and in Northern Appalachia and the Central West coal production is projected to grow at a slower rate than currently expected. Central Appalachia and the Western Northern Great Plains are projected to increase their production since the legislation benefits the producers of low-sulfur coal. The large shifts in regional coal production indicated in this study are likely to result in (1) a major redistribution in the employment of coal miners, and (2) shifts in regional economies as revenues from coal production in individual States are affected. No analysis has been made of the social costs of the shifts in coal production and their effects on employment of coal miners.

- Five States--Ohio, Missouri, Indiana, Pennsylvania, and Illinois--that account for 50 percent of the projected reduction in 1995 SO_2 emissions would have higher electric utility capital expenditures, higher electricity prices, and lower State coal production with this legislation. In the base case with the legislation minus the base case projected without it, the increases in capital expenditures for the five States range from $185 million to $1,037 million (in 1980 dollars). Electricity prices increase 1.2 to 3.3 mills per kilowatthour (in 1980 dollars) among the five States, and State coal production in 1995 would decline by 0.3 to 37 million tons.

Benefits from the proposed amendments include improvements in air quality. Additional environmental benefits may occur from improved water and wildlife, agriculture and forestry, greater longevity of man-made structures, and better human health. Because such benefits are as yet unproven, it cannot be determined if their value will be more than, less than, or equal to the total costs of reducing emissions.

As stated earlier, this analysis assumes a minimum-cost response by electric utilities for complying with the legislation. These projections are based on current laws and regulations, and as such they can be viewed as likely only if no future changes in laws or regulations occur. If additional coal mine safety laws are enacted in the future, or if restrictions are placed on electric utilities in their selection of options, the cost increases will likely be higher than those reported here.

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[2] Energy Information Administration, Office of Energy Markets and End Use, Monthly Energy Review, DOE/EIA-0035 (83/04) (Washington, D.C., April 1983), p. 92.

1. INTRODUCTION

Acid rain is one of the major environmental issues of the 1980's. Fourteen bills were submitted to the 97th Congress (seven in the House and seven in the Senate) for the purpose of controlling acid rain or related air quality problems. Proposals for controlling acid rain usually focus on the electric utility industry as a major source of emissions that result in acid rain. These precursory emissions are sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

"Acid rain," more properly termed "acid deposition," refers to both the wet and dry depositing of acids from the atmosphere, predominantly acids of sulfur and nitrogen. The standard measure of acidity (pH) is a numeric scale falling from 14 (alkaline) to 0 (acid). Each one-unit drop in pH value indicates a tenfold increase in acidity. A pH of 7 is neutral. The complex chemical interactions in the atmosphere among sulfur and nitrogen and other elements (including ozone, carbon dioxide, volatile organic compounds, particulates, and metal catalysts), which produce acid deposition, are not well understood.

Sulfur and nitrogen emissions are both natural and man-produced. Worldwide, natural sulfur emissions from seaspray evaporation, organic decomposition, and volcanoes comprise about 60 percent of total emissions. In the eastern United States, however, only about 10 percent of total sulfur emissions are believed naturally produced.[1] Far less is known about nitrogen emissions, although it is estimated that between 5 and 25 percent of total nitrogen emissions in North America are produced naturally.[2]

Total 1980 man-produced emissions in the United States for SO_2 and NO_x were 26.6 and 21.3 million tons, respectively.[3] The distribution of these emissions by source is shown in Figure 1.

This report projects the amount of SO_2 that will be emitted by electric utility coal- and oil-fired boilers in 1995 under the limitations of the current Clean Air Act, and analyzes the impact of Senate bill S.3041, Clean Air Act Amendments of 1982, which calls for reducing SO_2 emissions from major stationary sources in the eastern United States. The report further analyzes the effects of the proposed amendments on the electric utility industry, including the added capital expenditures required to reduce SO_2 emissions and the resulting effects on the cost of electricity. It also examines how reducing SO_2 emissions by electric utilities affects the coal industry, including shifts in coal production to low-sulfur coal. Finally, the potential benefits from the reduction of SO_2 emissions are discussed.

In Chapter 2, a brief history of the Clean Air Act is presented, along with regulations for SO_2 emissions for electric utility coal-fired boilers. Provisions of

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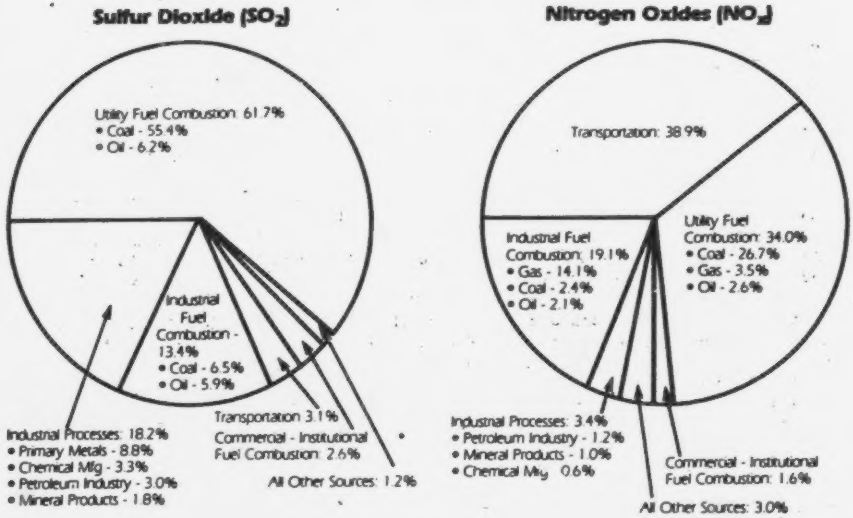
[1] GCA Corporation, Technology Division, "Acid Rain Information Handbook, Draft Final Report," (Bedford, Massachusetts, January 1983), pp. 2-10.

[2] Jennifer A. Logan, "Nitrogen Oxides in the Troposphere: Global and Regional Budgets," Center for Earth and Planetary Physics (Harvard University, December 1982), Table 10. (Submitted for publication to Journal of Geophysical Research.)

[3] United States-Canada Memorandum of Intent on Transboundary Air Pollution, "Emissions, Costs, and Engineering Assessment," United States/Canada Work Group on Emissions, Costs, and Engineering Assessments, Work Group 3B, Final Report (June 1982), Table B.2.1, p. 46 and Table B.2.3, p. 48.

Figure 1. U.S. Distribution of Sulfur Dioxide and Nitrogen Oxides - Man-Produced Emissions by Source, 1980



Note: Minor Subtotals of Emissions Sources Are Not Shown.

Source: GCA Corporation, Technology Division, "Acid Rain Information Handbook," Draft Final Report, (Bedford, Massachusetts, January 1983) pp. 2-15, 2-16.

Senate bill S.3041 regarding the proposed reduction in SO_2 emissions in the eastern United States by 1995 are described in detail.

The methodology for comparing the impact on SO_2 emissions by 1995 under provisions in the Clean Air Act with and without the proposed amendments is described in Chapter 3. The data assumptions and computer models used for analyzing SO_2 emissions in 1995 and determining the financial impacts on the electric utilities and electricity costs are described.

Chapter 4 presents an analysis of the impact on the electric utility industry of the proposed reductions in SO_2 emissions that would be required of utilities by 1995. The analysis considers additional capital requirements, ability of the utilities to raise capital, and the resulting changes in the cost of electricity.

Chapter 5 covers the impact of the proposed amendments on the coal industry, including possible changes in electric utility coal demand, and in the characteristics of coal that can be burned by utilities. Chapter 6 discusses potential benefits from reductions in emissions. Finally, Chapter 7 summarizes the findings.

7. CONCLUSIONS

Findings of This Study

The changes proposed by the Clean Air Act Amendments of 1982 would result in a reduction of over 50 percent in the amount of SO_2 projected to be emitted by electric utilities in 1995. However, this represents only 20 percent of the natural and man-produced SO_2 and NO_x emitted in the 31 States in 1980. (See Appendix B.)

Major findings of this report assessing the impacts of the proposed legislation are summarized below:

- Switching to low-sulfur coal is projected to be the preferred choice of electric utilities to reduce SO_2 emissions. Capital expenditures are not required for 60 percent of the boilers that convert to low-sulfur coal. However, if the transportation rates for shipping coal increase substantially, utilities in the Midwest would likely continue using high-sulfur coal produced in their own or nearby States, and would retrofit more power plants with an FGD system.

- Cumulative capital expenditures in the 31 States affected by the proposed legislation are projected to increase by $7.2 billion to $17.8 billion, in 1980 dollars, for the range of scenarios considered. Most of this increase occurs from 1991 through 1995 and represents 4.4 to 9.6 percent of projected total capital expenditures by all utilities in the 31 States for that period.

- Average electricity prices are projected to increase by 0.9 to 3.7 mills per kilowatthour across the various scenarios in 1995, as utilities must recover higher capital expenditures, fuel expenditures, and operating and maintenance costs. The 1982 average retail electricity price for privately owned utilities was 52.8 mills per kilowatthour in 1980 dollars.

- The coal industry is likely to experience large shifts in the amount of coal produced in the different regions. In the Midwest, coal production is projected to drop below its 1980 level, and in Northern Appalachia and the Central West coal production is projected to grow at a slower rate than currently expected. Central Appalachia and the Western Northern Great Plains are projected to increase their production since the legislation benefits the producers of low-sulfur coal.

- Five States--Ohio, Missouri, Indiana, Pennsylvania, and Illinois--that account for 50 percent of the projected reduction in 1995 SO_2 emissions would have higher electric utility capital expenditures, higher electricity prices, and lower State coal production with this legislation. In the base case with the legislation minus the base case projected without it, the increases in capital expenditures for the five States range from $185 million to $1,037 million (in 1980 dollars). Electricity prices increase 1.2 to 3.3 mills per kilowatthour (in 1980 dollars) among the five States, and State coal production in 1995 would decline by 0.3 to 37 million tons.

Benefits from the proposed amendments include improvements in air quality. Additional environmental benefits may occur from improved water and wildlife, agriculture and forestry, greater longevity of man-made structures, and better human health. Because such benefits are as yet unproven, it cannot be determined if their value will be more than, less than, or equal to the total costs of reducing emissions.

Comparison with Other Studies

The following studies have also been produced analyzing Senate Bill S.3041 or S.768, a similar bill, introduced in the 98th Congress:

- ICF, Inc., Analysis of a Senate Emission Reduction Bill (S.3041), Report for the Environmental Protection Agency (EPA), February 1983.
- National Economic Research Associates, Inc. (NERA), A Report on the Results from the Edison Electric Institute Study of the Impacts of the Senate Committee on Environment and Public Works Bill on Acid Rain Legislation (S.768), Prepared for the Edison Electric Institute, June 20, 1983.
- Peabody Holding Company, Inc., Economic Impacts of Senate Environment and Public Works Committee Acid Rain Legislation 1983.

Comparisons of the results of this EIA study with other analyses are included here to highlight the differences and similarities in the findings. Since the other reports do not address the sensitivity of the projections to different assumptions about the rate of growth in electricity demand or changes in railroad rates for shipping coal, only the results for the EIA base case are included for comparison.

Each study reports projected cost and coal production impacts in different ways. For example, some studies project increases in the annualized costs of producing electricity and others project capital expenditures and revenue requirements. Also, the methods used to estimate these impacts vary from study to study. This section briefly discusses each methodology, the underlying assumptions, the actual published values and how those values are adjusted for comparison and explains the differences.

Methodology

The projections included in this report and in the EPA report prepared by ICF, Inc., use similar linear program models of coal production and electric utility dispatching. The projections are developed by minimizing the marginal cost of producing electricity in each region, given constraints on the amount of available capacity and the required reduction in SO_2 emissions. This approach assumes that the utilities in each region operate similarly to a centrally dispatched power pool, and that decisions on how to reduce SO_2 emissions are based on an economic choice.

In addition, financial impacts were projected for the EIA study with a financial accounting model called the National Utility Financial Statement Model. Income statements, balance sheets, and other financial factors are developed for each region, based on construction and dispatch decisions forecast by the linear programming model and on State Public Utility Commission rate-making practices.

The NERA report prepared for the Edison Electric Institute (EEI) is based on a survey of 24 utilities in the 31 States affected by the legislation. Most utilities in the survey compared the long-term cost effectiveness of retrofitting with FGD versus fuel switching for each plant. These companies would account for 44 percent of the 8-million-ton reduction in SO_2 emissions required by the legislation. The utilities provided estimates of how the reduction would be achieved and the costs of their compliance strategies.

The Peabody Holding Company report was developed with an accounting model that calculated the cost for each plant to reduce SO_2 emissions by the required amount. It was assumed that low-sulfur coal would be used whenever possible to satisfy an emission limit that was equal for all plants in a State. When low-sulfur coal could not meet this emission standard, it was assumed that the plant would retrofit with FGD equipment.

Underlying Assumptions

The underlying assumptions of the various studies of the impacts of S.3041 are shown in Table 15. The major differences in the underlying assumptions are discussed below.

All four studies in Table 15 are based on the State apportionment of the 8-million-ton annual reduction in SO_2 emissions specified in the legislation. The EIA study is based on intrastate trading of SO_2 reductions, with a small amount of interstate trading (up to 5 percent of each region's SO_2 emission limit). The EPA study prepared by ICF, Inc., has three methodologies: intrastate trading, interstate trading, and an emission limit of approximately 1.5 pounds of SO_2 per million Btu for each unit. For comparison purposes, the cost data from the intrastate methodology were used from the EPA study.

The EEI report is based on the assumption that each utility will meet a required reduction in emissions. The required State reduction was apportioned among sources within each State, based on 1980 emissions in excess of 1.5 pounds per million Btu. The Peabody Holding Company applied the State apportionment of the 8-million-ton reduction to individual power plants and assumed that each power plant in a State would satisfy the same emission standard.

The EIA and EPA studies have a phased implementation to reduce SO_2 emissions, while the EEI and Peabody Holding Company reports provide impacts for the first year the legislation is in effect, and EEI also gives 5-year levelized effects. Both the EPA and Peabody studies offset industrial SO_2 emission growth, and in addition the EPA report reduced industrial SO_2 emissions. The electricity demand growth in the EIA study varies by region, with a national increase of 2.9 percent annually from 1980 to 1995, compared with the EPA study figures of 1.5 percent from 1983 to 1985 and 2.7 percent from 1985 to 1995.

The FGD retrofit costs used in the studies vary considerably. In 1980 dollars, the costs are $125 to $160 per kW in the EIA report, $159 to $232 per kW in the EPA study, $145 to $370 per kW in the EEI study, and approximately $293 per kW in the Peabody report. The retrofit costs in the EIA study are in the lower range, because the costs for one or two spare modules were not included. In addition, it was assumed that small or old units, which have higher retrofit costs, would not retrofit. Spare modules for reliability of the pollution control equipment could raise the cost by 20 to 30 percent (for one spare) or 50 to 60 percent (for two spares). Since the SO_2 emissions standard specified in this legislation is on an annual basis, and not over 24 hours or less, plants could be operated when the FGD equipment was not 100 percent available and remain in compliance. Therefore, it was assumed that the utility would avoid the additional cost of redundant units. The EIA and EEI studies also included a cost for modifying boilers and electrostatic precipitators when necessary to burn low-sulfur coal, whereas the EPA and Peabody studies did not.

Table 15. Underlying Assumptions in Studies of S.3041

Assumption	EIA	ICF, Inc. (EPA)	NERA, Inc. (EEI)	Peabody Holding Co.
SO_2 8-million-ton reduction	Based on State apportionment specified in the legislation. Intrastate trading with small amount of interstate trading allowed (5 percent of each State's allocation).	Based on State apportionment specified in the legislation. Intrastate trading.	Based on State apportionment specified in the legislation. Applied to utility level for 24 utilities (3.5-million-ton reduction).	Based on State apportionment specified in the legislation. Applied to plant level.
NO_x limitation	None except as limited by current SIPs.	None except as limited by current SIPs.	None.	None.
Area of impact	31 States.	31 States.	24 utilities in 31 States.	31 States.
Phased implementation or implementation in 1 year	Phased.	Phased.	1 year.	1 year.
Utility and/or industry reduction	Utility.	Utility and industrial.	Utility.	Utility and industrial.
Utility SO_2 emissions growth offset	Yes.	Yes.	Yes.	Yes.
Industry SO_2 emissions growth offset	No.	Yes.	No.	Yes.
Cost of compliance with existing SIPs included	No.	No.	Yes.	Yes.
Growth rate in electricity demand	2.9 percent (base case).	1.5 percent, 1980-1985. 2.7 percent, 1985-2010.	Not specified.	Not specified.
FGD retrofit costs (1980 dollars)	$125 to $160 per kW.	$159 to $232 per kW.	$145 to $370 per kW (varies by utility).	12.5 mills/kWh annualized cost[a]
FGD redundancy (spares)	No.[b]	Yes.	Yes.	Yes.
Boiler modification cost for low-sulfur coal (1980 dollars)	$70 per kW.	None.	Included but not identified.	None.
ESP modification cost for low-sulfur coal	$50 per kW.	None.	Included but not identified.	None.

[a] The FGD annualized cost includes capital and operation and maintenance costs and relates to an approximate FGD capital cost of $293 per kW in 1980 dollars.

[b] It was assumed that spares would not be included, because the legislation only requires SO_2 emission levels to meet an annual standard. Therefore, outage of an FGD module would not necessarily require the plant to be shut down. If spares had been included, the cost of retrofit would be 20 to 30 percent higher for one spare or 50 to 60 percent higher for two spares.

Sources: EIA, present study; ICF, Inc., Analysis of a Senate Emission Reduction Bill (S.3041), Report for EPA, February 1983; NERA (National Economic Research Associates, Inc.), A Report on the Results from the Edison Electric Institute Study of the Impacts of the Senate Committee on the Environment and Public Works Bill on Acid Rain Legislation (S.768), Report for Edison Electric Institute, June 20, 1983; Peabody Holding Company, Inc., Economic Impacts of Senate Environment and Public Works Committee Acid Rain Legislation 1983.

Finally, when a power plant is currently not in compliance with existing State implementation plans (SIPs), the cost to come into compliance was subtracted from the cost of compliance with S.3041 in the EIA and EPA studies, since these costs would be incurred even without the new legislation. However, in the EEI and Peabody studies, these costs were included as costs of compliance with S.3041.

Comparisons

Table 16 presents the projections from the four reports. If the estimate published in the report has been modified for more direct comparison, the original value is listed in the left column under each study name, with the adjusted value on the right. For example, the EIA study reports all financial impacts in 1980 dollars. These values are inflated to 1982 dollars for comparison with the other studies.

The revenue requirements projected consist of all operating and capital costs of providing service in a particular year. In the EIA study, the amount of capacity modified each year with pollution control equipment was assumed to be evenly divided over the years 1991 to 1995, to ensure the least possible disruption of system reliability. Therefore, the revenue requirements projected for 1995 are not first-year requirements on all the capital expenditures; they are first-year requirements for one-fifth of the expenditures, second-year requirements for an additional one-fifth, and so forth.

The EEI report presents the increased revenue for the first year the legislation is in effect, assuming that all capital expenditures enter the rate base in the same year for the 24 utilities surveyed. The levelized revenue requirements for the first 5 years of operation are also presented. Therefore, to compare with the EIA projections, the 5-year levelized value, although not exactly the same, is more useful. Also, the EEI's published projections are for only 24 utilities that account for 3.5 million tons or 44 percent of the 8-million-ton reduction in SO_2 emissions. If we assume that these 24 utilities are a representative sample accounting for 44 percent of the SO_2 reduction, the total increase in revenue requirements for the 31 States would be 2.27 times the total for the 24 utilities. After this adjustment, the EEI estimate is higher than the EIA estimate, for the following reasons: (1) the amount of capacity that is projected to be retrofit with FGD is greater; (2) the capital cost of retrofits is higher, because spare modules are included; (3) the premium projected for the price of low-sulfur coal versus high-sulfur coal is higher; and (4) if a plant is not in compliance with existing SIPs, the cost of compliance is not deducted from the cost of compliance with S.3041. In addition, the intrastate trading allowed in the EIA report could lower the cost of compliance.

In the initial years of compliance with S.3041, capital expenditures for retrofits would result in a greater increase in the price of electricity than would switching to low-sulfur coal. Therefore, the projected price increases are higher for the studies with more capacity projected to be retrofit. For comparison, the percentage increases reported by EPA and EEI were converted to mills per kilowatthour. The ICF study gave a percentage increase above the 1980 residential price of electricity, and the EEI report provided utility-specific percentage increases over 1982 rates. The EIA and EPA results are average increases for the 31 States, while the range given by EEI represents the lowest and highest increases among the 24 utilities.

Annualized costs were provided in the EPA and Peabody Holding Company studies. This calculation levelizes the capital expenditures over 15 to 30 years, depending on the useful life of the equipment. An estimate of annualized capital costs for the EIA study was calculated for comparison purposes, using the fixed-charge factors developed by ICF for the EPA study. This annualized capital cost is added to the EIA projections for fuel and operating and maintenance expenditures in 1995 to provide an estimate of total annualized costs. It should be noted that the EIA results displayed in the column labeled "1980 Dollars" in Table 16 do not include the annualized capital cost estimates, whereas those in the column labeled "1982 Dollars" do include them. The EPA report projects the annualized costs for utilities to be highest in 1995 and then decline to $2.4 billion (1982 dollars) in 2010. The other studies did not estimate cost impacts beyond 1995. The Peabody study has higher total annualized costs because ICF estimates for FGD equipment were inflated by 25 percent to account for uncertainty in the cost of retrofitting units. In addition, the Peabody study assumed that each power plant within a given State would have to meet the same emission limit. Higher costs of compliance occur when no trading of reductions within a utility or State is allowed.

The EPA report is the only study that evaluated the impact of the legislation on the industrial sector. The projected annualized costs (in 1982 dollars) for the industrial sector are $0.6 billion in 1995, $1.2 billion in 2000, and $1.7 billion in 2010. Total annualized costs projected in the EPA report for electric utilities and industry are $3.5 billion in 1995, $3.5 billion in 2000, and $4.1 billion in 2010.

The estimates of capital expenditures will depend on the amount of capacity projected to retrofit, the cost of retrofits, and whether additional costs such as boiler and electrostatic precipitator (ESP) modifications to burn low-sulfur coal are included. The economic choice for retrofitting versus switching to low-sulfur coal depends on the time horizon used for the cost comparison, the estimated difference in delivered price of low-sulfur versus high-sulfur coal, and any additional costs for using low-sulfur coal. The EEI study has some of the highest retrofit costs and also projects the most capacity to be modified. The estimated premium for low-sulfur versus high-sulfur coal ranges from $5 to $32 per ton (1982 dollars). Several utilities surveyed reported that in the longer term (the time horizon is not specified), the costs of retrofitting with FGD would likely be lower than the costs of switching to low-sulfur coal.

The EPA report projects less retrofitting, because the 15-year levelized costs of retrofitting a plant and using higher sulfur coal were higher in most cases than the projected costs of switching to low-sulfur coal. The EIA results are between those of the other two studies. Projected capital expenditures are higher than those in the EPA report for the following reasons: (1) more capacity is projected to retrofit with FGD because of the lower capital cost estimates; (2) additional costs to modify boilers and ESPs to use low-sulfur coal are included; and (3) costs of new capacity and transmission lines to retire more of the old units are also included. The EIA study projects less capacity to retrofit than the EEI study. One factor in this difference is the lower estimated premium for low-sulfur versus high-sulfur coal. In the EIA report, the premium varies by region, ranging from $10 to $25 (1982 dollars) per ton. The Peabody report assumed that switching to low-sulfur coal would be used unless the emission standard could not be met. The premium for low-sulfur versus high-sulfur coal is assumed to be $5 per ton higher than the 1982 delivered price of low-sulfur versus high-sulfur coal.

Shifts in coal production also depend on the amount of capacity projected to retrofit with FGD equipment. Less coal production will be displaced when more retrofits are projected. EEI did not estimate the impact on the coal industry. The other studies, which all project more switching to low-sulfur coal than EEI, estimate the shift in

Table 16. Comparison of Studies of the Impacts of S.3041

	Source of Estimate						
	EIA, Present Study, June 1983		ICF, Inc., Prepared for EPA, February 1983 (1982 Dollars)		NERA, Inc., Prepared for EEI, June 1983 (1982 Dollars)		Peabody Holding Company, No Date (1982 Dollars)
Impact of Legislation	(1980 Dollars)	(1982 Dollars)			3.5 million tons[a]	8.0 million tons[b]	
Electric Utilities (31-State Region)	As Reported	Adjusted	As Reported	Adjusted	As Reported	Adjusted	As Reported
Financial							
Increase in 1995 Revenue Requirements (Billion Dollars)	3.9	6.0	—	—	5.1[c] 4.0[d]	11.6[c] 9.1[d]	—
Increase in 1995 Average Electricity Prices (Percent)	—	—	2.9[e]	—	3.9-33.8[c,f] 3.9-30.0[d,f]		—
(Mills per Kilowatthour)	2.7	3.1	—	1.6[g]		2.4-33.0[c] 2.4-23.3[d]	—
Increase in 1995 Annualized Costs (Billion Dollars)							
Utility	2.6[h]	4.1[i]	2.9	—	—	—	—
Industrial	—	—	0.6	—	—	—	—
Total	2.6[h]	4.1[i]	3.5	—	—	—	7.8
Incremental Cumulative Capital Expenditures, 1983 to 1995 (Billion Dollars)							
FGD (Scrubbers)	2.8	3.2	2.6	—	—	—	—
Boiler Modification	2.1	2.4	—	—	—	—	—
Other[j]	3.7	4.3	—	—	—	—	—
Total	8.6	10.0[k]	—	—	15.3	34.8	—
Operations							
Capacity Retrofit with FGD (Gigawatts)	21.8		7.8		39.2	89.1	—
Capacity Converting to Low-Sulfur Coal (Gigawatts)	99.1		—		—	—	—

Coal Production in 1995 (Million Tons)	w/o S.3041	with S.3041	Percent change	w/o S.3041	with S.3041	Percent change			
Northern Appalachia	242	203	-16	213.0	154.8	-27	—	—	170 million tons of coal displaced in 1995; 43,000 mining jobs lost
Central Appalachia	346	439	+27	294.8	347.1	+18	—	—	
Southern Appalachia	34	31	-9	25.8	25.4	-2	—	—	
Midwest	198	111	-44	181.9	91.8	-50	—	—	
West	476	532	+12	584.6	679.6	+16	—	—	
Total	1,296	1,316	—	1,300.1	1,298.7	—	—	—	

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[a] Estimate assuming a reduction of 3.5 million tons in SO_2 emissions by 24 utilities.

[b] Estimate of 8-million-ton reduction in SO_2 emissions in the 31 States, calculated by EIA for the present comparison by multiplying the EEI figure by a factor of 2.27.

[c] Estimate for first year (1993).

[d] Estimate for 5 years (levelized, 1993-1997).

[e] Percent of 1980 residential price of electricity.

[f] Percent of 1982 rates for each utility. The range represents the lowest and highest increases among the 24 utilities.

[g] The price increase was calculated by multiplying the percent increase (2.9) by the 1980 average residential price reported in the Energy Information Administration, Monthly Energy Review.

[h] Includes operation and maintenance and fuel costs only.

[i] Includes capital, operation and maintenance, and fuel costs.

[j] Includes new transmission lines and new capacity.

[k] Total does not equal sum of components, due to independent rounding.

coal production. EIA projects a displacement in 1995 of 148 million tons, mostly in Northern Appalachia, the Central West, and the Midwest. Peabody Holding Company projects a displacement of 170 million tons, and ICF projects a displacement of 149 million tons.

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MITIGATING ACID RAIN: IMPLICATIONS FOR HIGH-SULFUR COAL REGIONS

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May 16, 1983

[Note: The following has been excerpted from the above named report. The complete report has been retained in committee files.]

MITIGATING ACID RAIN: IMPLICATIONS FOR HIGH-SULFUR COAL REGIONS*

INTRODUCTION

In an effort to begin mitigating acid rain damage, several bills have been introduced in the 98th Congress to reduce sulfur oxide (SO2) and nitrogen oxides (NOx) emissions from utility and industrial plants. One bill, S. 768, represents the proposed program passed last year by the Senate Environment and Public Works Committee. It proposes to reduce SO2 emissions by 8 million tons over the next 12 years and to freeze NOx emission rates at their current levels. The bill does not specify the manner in which the reduction would be achieved, providing affected States with flexibility in meeting the mandated reduction.

A primary focus of the discussion on this bill has been the cost of compliance in terms of higher utility bills. Utilities have generally argued that political constraints will force them to place flue gas desulfurization (FGD) units on their plants, increasing electricity rates. The coal companies and the United Mine Workers Union have argued that utilities will switch from burning high-sulfur coal to lower-sulfur coal because switching is cheaper than installation of FGD units. Finally, analyses done for various Government agencies and interest groups have suggested that a "least-cost" mixture of FGD units and fuel switching may occur, which would minimize electricity rate increases. 1/ This final scenario tends to favor fuel switching over FGD units because of cost, but includes some FGD because of various technical, contractual, and site-specific constraints to fuel switching.

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* This paper is a follow-on report to Impact of Proposed Acid Rain Legislation on the Illinois Coal Industry, a CRS unnumbered report by Larry B. Parker, dated February 21, 1983, which is attached to this report as Appendix A.

In addition to affecting electricity prices, such a bill could have a strong impact on the coal industry in major coal-producing States. If a State attempts to minimize electricity rate increases from acid rain legislation, it will tend to maximize the impact on high-sulfur coal-producing States by favoring fuel switching over FGD units. If a State attempts to protect its local high-sulfur coal industry by insisting on FGD units, it will maximize the electricity rate impact of the legislation. However, these two issues have generally been discussed separately, preventing the tradeoff involved from being discussed fully. 2/

This paper examines tradeoffs between electricity rates and the high-sulfur coal industry by analyzing the effects of two reduction strategies on six States in two major coal-producing regions: (1) the Eastern Interior Basin (Illinois, Indiana, western Kentucky), and (2) northern Appalachia (Ohio, Pennsylvania, northern West Virginia). The discussion is divided into four parts: (1) background on coal-producing areas; (2) analysis of the effect acid rain legislation would have on those areas, focusing on particular counties; (3) discussion of factors with potential to alleviate identified impacts; and (4) conclusion.

1/ Parker, Larry B. Summary and Analysis of Technical Hearings on Costs of Acid Rain Bills. CRS unnumbered report prepared for the Senate Committee on Environment and Public Works, July 26, 1982.

2/ There have been attempts by some opponents of acid rain legislation to combine the high unemployment figures of the coal companies' projections and the high electricity rate increases of utility companies' projections in one "disaster" scenario. Such an extreme scenario is not realistic. If the utilities used FGD on a plant, they would not also switch to low-sulfur coal in that plant. Utilities switching to low-sulfur coal would not also install FGD.

CONCLUSION

If economic forces were allowed to work unhindered, enactment of an 8-million-ton SO2 reduction program could have a dramatic effect on the coal industries in Illinois, western Kentucky, and Ohio. Production losses projected here could raise unemployment rates in the coal-producing areas of these States by 11 to 18 percentage points, depending on the specific area. Even with broad economic growth, unemployment in these regions would be significantly affected.

A lesser but still significant impact would occur in Indiana. Projected increases in unemployment rates of 9 to 10 percent would increase residual unemployment in coal-producing counties. Only in Pennsylvania could the impact of acid rain legislation be considered minor, although even a minor disruption in an area with high residual unemployment might not be considered minor, if that unemployment continues through 1995.

The projected impact of acid rain legislation in northern West Virginia was more uncertain than in the other States. If inexpensive new technologies were available for utilities to install, the impact was fairly minor (2.4 percent). However, with assumption of FGD as the only alternative, the impact was severe: an additional 17 percent unemployment. Discussion of the reemployment potential of southern West Virginia and eastern Kentucky suggests that, assuming a moderate growth in the steam and metallurgical markets, unemployed miners or those projected to be unemployed in southern West Virginia and eastern Kentucky would absorb the jobs created by acid rain legislation. Hence, the effect would be to concentrate miner unemployment in the northern part of the State, while decreasing unemployment in the southern West Virginia and eastern Kentucky.

Assuming that SO2 reductions are deemed necessary, the West Virginia example suggests that the most comprehensive strategy for preventing the impacts identified here would be to employ a technology-based implementation plan. Such a plan would drive up electricity rates in affected States significantly if utilities were required individually to cover the cost of installing control equipment. However, if the country were to take national responsibility for reducing SO2 emissions, a broad-based user fee on electricity generated could be imposed to cover the capital costs of control technologies, involving only a small increase (generally under 5 percent) in electricity rates.

A second possibility for lowered consumer rates is the emergence of new technologies such as LIMB, AFBC, and low-NOx burners. To ensure that these technologies would be available for use in an acid rain program, Congress may wish to consider methods to accelerate their development and commercialization.

Besides preventing the unemployment impacts discussed here, the capital investment in control technologies would expand a growing air pollution control industry, creating employment. This increased employment could more than balance the indirect employment impacts of high electrical bills. However, to implement a technology-based control strategy, with or without a user fee, would require a national commitment to the Nation's high-sulfur coal industry, and to the Midwest in general. Such a debate could be similar to that over 1977 amendments to the Clean Air Act regarding percentage reduction, although the outcome might be different.

Of the mitigating factors investigated, the other one which may provide significant relief to the high-sulfur coal industry is development of new markets. From the discussion, it would appear that the northern Appalachia region would have a greater chance of obtaining new markets for its coal than the Eastern

Interior Basin. However, there is little agreement on the potential impact of new markets and any prediction would be very speculative. Unforeseen future oil shortfalls or price escalations could improve the market for coal substantially.

In sum, the thrust of economic forces to minimize the electricity consumers' cost under acid rain legislation would tend to maximize the adverse impact of such legislation on the high-sulfur coal industry. The Congress may wish to consider this tradeoff between electricity rates and coal employment in determining any implementation strategy for reducing SO2 and NOx emissions.

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IMPACT OF PROPOSED ACID RAIN LEGISLATION ON THE ILLINOIS COAL INDUSTRY

Prepared for
Senate Subcomittee on Energy, Nuclear
Proliferation, and Government Processes,
Senate Governmental Affairs Committee

[Note: The following has been excerpted from the above named report. The complete report has been retained in committee files.]

by
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February 21, 1983

TP 400 C

IMPACT OF PROPOSED ACID RAIN LEGISLATION ON THE ILLINOIS COAL INDUSTRY

INTRODUCTION

In an effort to begin mitigating the acid rain problem, several bills were introduced in the 97th Congress to reduce sulfur oxide (SO2) and nitrogen oxides (NOx) emissions from utility and industrial plants. In August 1982, the Senate Environment and Public Works Committee passed a proposed program to reduce SO2 emissions by 8 million tons over the next twelve years and to freeze NOx emission rates at their current level. The bill does not dictate the manner in which the reduction would be achieved, providing affected States with flexibility in meeting the mandated reduction. 1/

A primary focus of the discussion on this bill has been the cost of compliance in terms of higher utility bills. Utilities have generally argued that political constraints will force them to place flue gas desulfurization (FGD) units on their plants, increasing electricity rates. The coal companies and United Mine Workers Union have argued that utilities will switch from burning high-sulfur coal to lower-sulfur coal because switching is cheaper than FGD units. Finally, analyses done for various government agencies and interest groups have suggested that a "least-cost" mixture of FGD units and fuel switching may occur which would minimize electricity rate increases. 2/ This

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1/ See: Title I, Section 120 of S. 3041. Clean Air Act Amendments of 1982. Approved by the Senate Environment and Public Works Committee, August 1982. Senate Report No. 97-666, 97th Cong., 2nd sess.

2/ See: Parker, Larry B. Summary and Analysis of Technical Hearings on Costs of Acid Rain Bills. Prepared for the Senate Committee on Environment and Public Works, July 26, 1982. CRS unnumbered report.

final scenario tends to favor fuel switching over FGD units because of cost, but includes some FGD because of various technical, contractual, and site-specific constraints to fuel switching.

A "cost" issue which has not been addressed adequately is the impacts of such a bill on the coal industry in major coal-producing States. 3/ If a State attempts to minimize the electricity rate increases from acid rain legislation, it will tend to maximize the impact on high-sulfur coal-producing States by favoring fuel switching over FGD units. If a State attempts to protect its local high-sulfur coal industry by insisting on FGD units, it will maximize the electricity rate impact of the legislation. However, these two issues have generally been discussed separately, preventing the tradeoff identified above from being discussed fully. 4/

This paper examines tradeoffs between electricity rates and the high-sulfur coal industry by analyzing the effects of a "least-cost" reduction scenario for the coal producing areas of Illinois. The discussion is divided into four parts: (1) background on coal producing areas in Illinois; (2) analysis of

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3/ The major studies on the effect of acid rain bills on the coal industry have been done by Peabody Coal Company and the United Mine Workers Union. These studies project massive unemployment in most eastern coal producing States. However, there are two major problems with the studies which limit their usefulness. First, the studies are based on a ten million ton requirement which is achieved entirely by fuel switching. Besides being a technical impossibility due to factors such as boiler design, the "least cost" studies show that in some cases, due to contractual or site specific circumstances, fuel switching is not an economical alternative to FGD. Hence, the unemployment projections are overstated. Second, the studies do not attempt to address the issue of job creation in low sulfur coal areas as a possible mitigating factor.

4/ Indeed, there have been attempts by some opponents of acid rain legislation to combine both the high unemployment figures of the coal companies' projections and the high electricity rate increases of the utility companies' projections into one "disaster" scenario. As indicated above, such an extreme scenario would not happen. If the utilities use FGD on a plant, they would not also fuel switch that plant to low-sulfur coal. If the utilities switch to low-sulfur coal, they would not also install FGD.

the effect acid rain legislation would have on those areas, focusing on particular counties; (3) discussion of potential mitigating factors to the impacts identified; and, (4) a conclusion.

CONCLUSION

Assuming economic forces were allowed to work unhindered, enactment of an 8 million ton SO2 reduction program could have a dramatic effect on the Illinois coal industry. Employing a least-cost scenario for electricity consumers would entail a 25.6 million ton loss in production, approximately 40 percent of Illinois' 1980 production. For the southern Illinois counties examined here, such a loss would almost double that area's 1980 unemployment rate from 11 to 21 percent and involve loss of about $200 million in personal income (about 17 percent of the counties total).

Of the mitigating factors investigated, only two provide any potentially significant relief for Illinois' industry: (1) finding new markets for Illinois coal, and (2) requiring FGD units on power plants where practical. Current uncertainty about future electricity demand, synthetic fuels, and export potential makes evaluation of the first alternative difficult. However, current circumstances suggest that new markets sufficient to overcome the deficit caused by the proposed program will not be forthcoming, at least through 1995.

Requiring FGD units on power plants where practical would be effective in reducing the production loss in Illinois from 25.6 to between 5 and 6 million tons, and creating jobs in the air pollution control industry. However, such a provision would require a consensus that the high-sulfur coal industry is sufficiently important for consuming States to pay higher electricity bills to maintain it. Such a debate could be similiar to that over the 1977 amendments to the Clean Air Act regarding percentage reduction.

In sum, a "least cost" scenario would not be least cost to the coal industry in Illinois. Indeed, for coal-producing counties in southern Illinois, the cost could be very high. The Congress may wish to consider this tradeoff between electricity rates and coal employment in determining any implementation plan for reducing SO2 and NOx emissions.

A Report on the Results From the Edison Electric Institute Study of the Impacts of the Senate Committee on Environment and Public Works Bill on Acid Rain Legislation (S.768)

Compiled and Prepared

by

National Economic Research Associates, Inc.

for

Edison Electric Institute

June 20, 1983

I. INTRODUCTION

During the past two years, Congress has considered a variety of legislative proposals to reduce emissions of sulfur dioxide and nitrogen oxides in the eastern United States. Two of the proposals have gained particular attention. The first is a 10 million ton sulfur dioxide reduction program introduced by Senator Mitchell and the other an 8 million ton sulfur dioxide reduction adopted last year by the Senate Committee on Environment and Public Works (currently Section 120 of S.768).

Several organizations, including the Environmental Protection Agency, Congress' Office of Technology Assessment and the Edison Electric Institute, have conducted macroeconomic studies of the impacts of these bills. It became apparent that there were several major shortcomings in the studies. These included the failure: (1) to consider company and site-specific problems retrofitting may entail; (2) to account for important factors that will affect the choice of scrubbers as compliance options--their capital requirements and the risks associated with operating them; (3) to acknowledge that states with substantial high sulfur coal reserves may constrain utilities from fuel shifting; (4) to recognize the institutional impediments for emissions trading in the context of an emissions reduction program; and (5) to adequately reflect problems inherent in emissions variability caused by, for example, extended outages at non-fossil plants. In addition, the method of reporting costs generally understated the initial rate impacts of adding scrubbers.

In an attempt to reduce the effects of these shortcomings, EEI developed an alternative approach to assessing the economic impacts of acid rain legislation. At the heart of the analysis was a survey of a number of utilities in the East. At the request of EEI, the National Economic Research Associates, Inc. (NERA) reviewed the methodology of the survey. In addition, NERA was asked to review each response and resolve major problems that emerged from this review and to compile the results. In this report we briefly discuss: (1) the survey, (2) the basis for EEI's concern with earlier analyses; (3) the key results from the survey; and (4) the results of our review.

II. THE SURVEY

The EEI Working Group on Economic Standardization developed a methodology to estimate the company-specific impacts of acid rain legislation. The Working Group had two goals. First, it sought to provide guidelines as to how key calculations should be done and on how the bill should be interpreted so that the responses would be as comparable as possible. Second, the Group wanted the utilities to develop their own compliance strategies-- scrubbing, fuel switching, etc.-- based on company-specific conditions and estimates of the costs of each strategy option. As a result, the analysis is unique in that it offers insights into how individual utilities would comply with the bill.

EEI recognized that with this approach responses would not be entirely comparable. However, EEI felt that the more accurate reflection of company-specific circumstances would outweigh this disadvantage.

In an effort to ease the task of estimating compliance costs, EEI's analysis asked member companies only to consider expenditures necessitated by the bill's requirements that sulfur dioxide emissions be reduced by 8 million tons and that increases in utility sulfur dioxide emissions above 1980 levels to be offset. In doing so, the analysis effectively assumed that there would be no costs associated with:

1. the bill's requirement that any post-1980 net increase in sulfur dioxide emissions from sources other than utilities be offset;
2. the bill's revocation of all sulfur dioxide State Implementation Plans relaxations granted since 1980;

3. the bill's retroactive and immediately effective ban on post-1980 increases in actual sulfur dioxide emission rates;
4. the bill's stipulation that utilities must comply with a 1.2 pound per million Btu systemwide average in states where compliance plans are not prepared or approved in a timely manner; and
5. the bill's prospective prohibition on increases in nitrogen oxide emission rates from sources other than utility coal conversions.

Since compliance with these five requirements would accelerate and enhance the rigor of the bill's reduction obligations, the legal interpretation on which EEI's analysis is based may tend to understate the costs of compliance.

The study involved 24 electric utilities in the eastern United States who responded to a questionnaire. The questionnaire consisted of four parts. In the first part, the utilities were asked to calculate the reduction in emissions they would be required to achieve by 1993 under the bill. The analysis assumed that the 8 million ton reduction would be apportioned among states (and sources within each state) on the basis of 1980 emissions of sulfur dioxide in excess of 1.5 pounds per million Btus. A copy of the instructions and an example of the questionnaire are given in Appendix A. The individual responses are in Appendix B. Appendix C includes an interpretation of the bill by Hunton & Williams.

The second part was for the utilities to describe the strategy they would use to achieve the required emissions reduction. In this part, the utilities indicated how much capacity they would retrofit with scrubbers, how much they would switch to lower sulfur fuels and how much they would retire. They were also asked to report the emissions reduction that would be achieved through each option.

In the third part, the utilities reported their estimates of the unit costs and other effects of each strategy option. For scrubbers, this included the capital and operating and maintenance (O&M) costs, the reduction in unit generating capability and the increase in unit outage rates. For units that would switch fuels, the utilities provided the premiums for lower sulfur coal or oil. In addition, the utilities gave the cost of replacement capacity and the annual fixed charge rates for capital expenditures.

The last part contained the annual cost impacts of the legislation. The impacts were reported in terms of annual revenue requirements, the increases in revenue requirements expressed as a percent of the most recent average electric rates (1981 or 1982) and the cost per household. These were reported for the first year of compliance (1993) as well as in levelized terms over the first five years (1993 through 1997). All costs were expressed in 1982 dollars.

The EEI methodology was designed to reduce the effects of the shortcomings of previous analyses (see Section III). However, the problems have not been entirely eliminated. Most utilities have not performed the detailed engineering and economic studies that would be necessary to identify and quantify all costs imposed by the legislation.

III. AREAS OF CONCERN WITH PREVIOUS STUDIES

As we have noted above, EEI had several main concerns with previous analyses of the proposed legislation--the manner in which impacts were assessed and the way in which the cost impacts were reported. In this section we discuss these concerns.

A. Areas of Potential Bias in Estimated Impacts

There are several specific areas in which the macroeconomic analyses may have systematically underestimated compliance costs. First, retrofitting scrubbers may entail costs far in excess of installing them at new plants. For example, at existing facilities there is often limited space available for scrubbers. This increases construction costs. Also, scrubber sludge may have to be trucked for off-site disposal. This increases the O&M costs. While industry-wide estimates of retrofit penalties have been made, the magnitude of these cost increases are site-specific and can vary widely. EEI concluded that the individual utilities can best assess these in light of their familiarity with plant-specific circumstances and their responsibilities for designing compliance plans.

Second, the ability to switch from coals of one quality to another in certain boilers may be limited unless major modifications are made. Fuel switching is an important, and often the most economic, method for achieving the emission reductions. However, if major boiler modifications are required, the economic advantages of fuel switching will be reduced, thereby raising compliance costs. Once again, in EEI's view, the need for major modifications can best be determined on a unit-by-unit basis by the utilities.

Third, political considerations may play an important role in determining the extent of fuel switching. In an effort to protect mining employment and mine-related jobs, eastern coal producing states may very well constrain fuel switching. For example, these limitations may be imposed as a matter of law, such as Section 125 of the Clean Air Act, or as a matter of policy, through technology-based control strategies. In EEI's judgment, the individual utilities will best be able to determine how such constraints will affect compliance strategies.

Fourth, the premium utilities pay for low sulfur fuels will play an important role in determining the compliance strategies that are selected and the costs of the legislation. Based on the experience of its members, EEI was concerned that the premiums for low sulfur coals projected in recent analyses of the legislation may be too low. To the extent that this is the case, the impacts of the legislation will be understated. As a result, the utilities were asked to provide their own estimates of low sulfur coal premiums and use them in estimating the impacts of the legislation on fuel costs.

Fifth, the other analyses either explicitly or implicitly assume some emissions trading will occur. This underestimates the company-by-company compliance costs for at least two reasons. It is uncertain as to the extent to which institutional barriers will limit emissions trading. Also, there will be transaction costs in trading emissions not recognized in these earlier studies.

Finally, the previous analyses apparently did not take into account the effects of events that could result in higher emissions. For example, an outage at a nuclear plant will increase fossil-fired generation and, as a result, sulfur dioxide emissions. EEI believes that utilities are best able to assess how this will affect their compliance strategies and costs. It should be noted, however, that many utilities did not take such factors into account in this study. Consequently, they have understated the cost of complying with the legislation.

B. Reporting the Cost Impacts

The other main area of concern was how the cost impacts were reported. In previous analyses of the legislation, the cost effects have been expressed as levelized annual costs. These were the sum of the annual capital charges, levelized over the life of the capital equipment, and the annual charges for fuel and O&M. This is certainly one measure of the impacts of the legislation. However, it does not reflect the large increase in electric rates that will occur in the first few years of compliance. This will occur because the legislation will raise utility capital expenditures (primarily required for retrofit scrubbers). During the first few years these capital expenses are in the rate base, the annual charges for them will be very high. These annual charges, combined with higher fuel and O&M expenses, can lead to large rate increases.

IV. SUMMARY OF RESULTS

The utilities involved in the study would account for 3.5 million tons, or 44 percent, of the 8 million ton emission reduction required by the Senate Committee bill. They indicated that a reduction of 4.5 million tons would be required to comply with the bill. The additional 1.0 million ton reduction would be necessary primarily to offset emissions growth. The responses show that the proposed legislation could have substantial impacts on electric rates. The increases in revenue requirements in the first year of compliance, 1993, expressed as a percent of the most recent rates (when all revenue requirements are expressed in 1982 dollars) were estimated to be as high as 53.8 percent. One-third of the utilities reported increases in excess of 20 percent and half of them indicated increases of at least 14 percent (see Table 1).

Households will bear, either directly or indirectly, the higher electricity costs. These increases in annual revenue requirements per household were estimated to be as high as $938 per household (in 1982 dollars).[1] One-third of the utilities reported the first year increases in costs per household will exceed $300 and half indicated increases of at least $220 per household.

In aggregate terms, the first year annual costs of the legislation will be considerable--$5.06 billion for the utilities in the study (see Table 2). A good part of this would be for the annual charges for retrofit scrubbers, although fuel switching also contributes to the cost increases. The capital expenditures for this retrofitting and for replacing capacity would be $15.30 billion (see Table 3).

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[1] The cost impacts per household are the increase in revenue requirements divided by the projected number of households for 1993. It should be noted that this will overstate the cost per household for customers of utilities with relatively large shares of industrial electricity sales. The reason is that the increased costs reflected in industrial electricity prices will be borne over broad geographical regions. At the same time, the cost per household will be understated for utilities with small shares of industrial electricity sales.

V. NERA REVIEW OF EEI SURVEY METHODOLOGY

We reviewed the methodology used in the EEI survey and found it to be sound. There are, however, areas of the analysis NERA would have approached differently. But, as we note below, the overall results would not be significantly affected by these alternative approaches. In this section we touch on these briefly. First, the EEI survey relied on company-specific estimates for the premiums for low sulfur coals. Our approach would have been to rely on prices that balanced regional supplies and demands for different sulfur content coals. However, after reviewing the results, we found that some companies reported premiums lower than what we would have projected and the premiums for other companies were higher. This suggests that the key results may not be significantly affected if EEI used an approach that reflected prices determined by balancing supply and demand.

Second, in converting capital expenditures to annual charges, the EEI example, and presumably many of the utilities, used the pre-tax discount rate based on the Electric Power Research Institute's methodology. We would have recommended using the after-tax rate. This would not affect the first year impacts, and would only slightly alter the levelized effects. Moreover, this is an issue about which there is not unanimity of opinion--some analysts advocate using the pre-tax rate and others the after-tax rate.

Finally, there is the issue of replacement capacity charges. Utilities in the study generally measured the replacement capacity requirements as the reduction in net dependable capacity caused by retrofitting scrubbers. They assumed the cost of providing the replacement capacity would be the cost for a new coal plant or an average of the costs for a coal plant and a combustion turbine. We would have recommended the following approach. In planning system reliability, utilities aim to maintain a reserve margin designed to achieve a specified level of reliability. Retrofitting scrubbers reduces the unit reliability and net dependable rating. Both of these changes lower system reliability. To maintain the desired level of reliability the reserve margin will have to be increased. How this increase in reserves is achieved will vary widely depending on the amount and mix of generating capacity and the growth in electricity demand. For some companies, where projected low demand growth and excess capacity combine to create high reserves, the cost will be the O&M expense for units that will otherwise not be maintained. Some systems may be able to enter into arrangements with other utilities that have excess capacity. Other systems may have to add capacity. This can be in the form of baseload units, peakers or a combination of the two depending on the existing capacity mix. Under these circumstances the replacement capacity costs would be higher. For most of the utilities in the study, replacement costs are a relatively small part of compliance costs. Consequently, had EEI used this approach the results would not have been fundamentally altered for these companies.

TABLE 1

COST IMPACTS ON RATE PAYERS OF SENATE BILL S.768[1]

(1982 Dollars)

	Increase as Percent of 1982 Rates[2]		Increase in Revenue Requirements Per Household[3]	
Utility	First Year[4]	Five Year Levelized	First Year[4]	Five Year Levelized
	(Percent)		(Dollars)	
	(1)	(2)	(3)	(4)
Florida Power & Light Co.	9.9%	5.0%	$180	$ 92
Tampa Electric Company	26.4	22.9	510	442
The Southern Company[5]	14.9	12.2	220	180
Illinois Power Company	22.3	18.1	344	279
Central Illinois P.S.	24.3	20.8	339	290
Public Service Indiana	28.0	24.5	478	417
Indianapolis P&L	31.5	25.6	486	394
New England Power Co.	3.9	3.9	49	49
Detroit Edison	13.2	11.8	221	198
Union Electric Company	19.8	18.1	312	285
Duke Power Company	4.9	4.3	110	96
Cincinnati G&E	18.4	14.3	275	214
Columbus & Southern Ohio (AEP[6])	7.9	6.2	95	76
Indiana & Michigan (AEP)[7]	53.8[8]	34.2	584[8]	378
Kentucky Power Co. (AEP)	11.2	9.8	190	166
Ohio Power Co. (AEP)[7]	51.6[8]	38.0	938[8]	699
Pennsylvania Electric	23.4	20.3	285	250
Pennsylvania P&L	10.7	9.6	44	39
VEPCO	7.5	6.4	107	91
Wisconsin Power & Light	12.8	11.3	208	183
Wisconsin Electric Power	15.0	12.3	233	191

[1] Results from EEI questionnaire on cost impacts of Senate Bill S.768.

[2] Some utilities used 1981 rates, escalated to 1982 dollars, as the base.

[3] The cost impacts per household are the increase in revenue requirements divided by the projected number of households for 1993 (see footnote 1, page 7).

[4] First year is generally 1993.

[5] Georgia Power Co., Gulf Power Co. and Mississippi Power Co.

[6] One of the AEP companies, Appalachian Power Co., would achieve the required emissions reduction through the normal retirement of 725 megawatts of capacity. As a result, there would be no impact on revenue requirements.

[7] The cost impacts reflect the amortization and depreciation for capacity added to replace prematurely retired units. These charges were included only for the number of years the units would not operate as a result of the legislation.

[8] These are the costs incurred in 1995, the first year the full impacts will be incurred.

ANNUAL COSTS UNDER SENATE BILL S.768[1]

(1982 Dollars)

Utility	First Year[2]	Five Year Levelized
	----(Million	Dollars)----
	(1)	(2)
Florida Power & Light	$ 436	$ 223
Tampa Electric Company	210	182
The Southern Company[3]	698	572
Illinois Power Company	179	146
Central Illinois P.S.	117	100
Public Service Indiana	225	198
Indianapolis P&L	170	137
New England Power Co.	53	53
Northeast Utilities	6	6
Boston Edison Company	19[4]	19[4]
Detroit Edison	384	342
Union Electric Company	279	254
Duke Power Company	143	125
Cincinnati G&E	193	151
Columbus & Southern Ohio (AEP[5])	55	44
Indiana & Michigan (AEP)[6]	387[7]	246
Kentucky Power Co. (AEP)	33	29
Ohio Power Co. (AEP)[6]	677[7]	499
Pennsylvania Electric	160	140
Pennsylvania P&L	166	149
VEPCO	226	191
Wisconsin Power & Light	56	49
Wisconsin Electric Power	198	162
Total for all Respondents	$5,061	$4,017

[1] Results from EEI questionnaire on cost impacts of Senate Bill S.768.

[2] First year is generally 1993.

[3] Georgia Power Co., Gulf Power Co. and Mississippi Power Co.

[4] These costs do not include the savings in revenue requirements that would be foregone by not converting to coal, which would become uneconomic under the bill.

[5] See Footnote 6 on Table 1.

[6] The cost impacts reflect the amortization and depreciation for capacity added to replace prematurely retired units. These charges were included only for the number of years the units would not operate as a result of the legislation.

[7] These are the costs incurred in 1995, the first year the full impacts will be incurred.

TABLE 3

IMPACTS ON CAPITAL EXPENDITURES OF SENATE BILL S.768[1]

(1982 Dollars)

Utility	Total Capital Expenditures (Million Dollars) (1)	Capacity Scrubbed (Megawatts) (2)	Capacity Lost Due to Scrubbing (Megawatts) (3)	Premature Retirements (Megawatts) (4)
Florida P&L Co.	$ 399	1,727	26	0
Tampa Electric Company	421	1,230	25	0
The Southern Company[2]	2,307	7,160	430	0
Illinois Power Company	593	1,800	231	0
Central Illinois P.S. Co.	266	900	15	0
Public Service Indiana	600	2,346	35	0
Indianapolis P&L Co.	399	1,150	115	0
New England Power Co.	0	0	0	0
Boston Edison Company	0	0	0	0
Northeast Utilities	0	0	0	0
Detroit Edison	943	3,000	96	0
Union Electric Company	869	3,400	55	0
Duke Power Company	348	1,200	60	0
Cincinnati G&E Company	466	1,427	57	80
Columbus & Southern Ohio (AEP[3])	183	366	37	0
Indiana & Michigan (AEP)	1,925[4]	2,210	221	900
Kentucky Power Co. (AEP)	141	390	39	0
Ohio Power Co. (AEP)	2,859[4]	3,185	318	1,080
Pennsylvania Electric Co.	222	950	29	0
Pennsylvania P&L Co.	314	1,515	61	0
VEPCO	1,189	2,843	199	0
Wisconsin P&L Co.	166	591	14	0
Wisconsin Electric Power	683	1,774	80	0
Total for all Respondents	$15,299	39,164	2,143	2,060

[1] Results from EEI questionnaire on cost impacts of Senate Bill S.768.

[2] Georgia Power Co., Gulf Power Co. and Mississippi Power Co.

[3] See Footnote 6 on Table 1.

[4] Includes the capital costs for the replacement of the capacity that would be prematurely retired [see column (4)]. However, the amortization and depreciation for this capacity were included in the annual cost impacts only for the number of years the units would not operate as a result of the legislation.

EXECUTIVE SUMMARY

The Edison Electric Institute (EEI) is concerned about the accuracy of macroeconomic studies regarding the costs of acid rain control legislation. These studies have not adequately assessed numerous utility-specific considerations which could significantly increase the cost of compliance. In an effort to address these concerns, EEI developed an alternative approach to evaluate the impacts of acid rain legislation adopted in 1982 by the Senate Committee on Environment and Public Works (reintroduced in 1983 as S.768). The heart of the analysis was a study of 24 utilities in the 31 eastern states. These companies account for 3.5 million tons, or 44 percent, of the 8 million ton reduction in emissions required by the bill. As part of the effort, EEI asked the National Economic Research Associates, Inc., to review the methodology and to review, compile and check the responses. The key results, in 1982 dollars, can be summarized as follows:

- The increases in electric rates for many utilities can be very high. One-third of the utilities reported that in the first year of compliance (1993) the increase in rates above those for the most recent years would exceed 20 percent and half reported increases above 14 percent (see Table 1).

- The increases in revenue requirements per household are equally large. One-third of the utilities reported that in the first year of compliance the increases would exceed $300 per household and half indicated increases in excess of $220 (see Table 1).

- Most of the utilities reported that their compliance strategy would include retrofitting scrubbers to existing coal plants. The capital expenditures for the scrubbers and other capital equipment would exceed $15 billion for the 24 companies.

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES
2101 Constitution Avenue Washington, D.C. 20418

ENVIRONMENTAL STUDIES BOARD

November 30, 1983

Honorable Max Baucus
United States Senate
SH-706 Hart Senate Office Bldg.
Washington, D.C. 20510

Dear Senator Baucus:

Your letter to Dr. Kasper of November 3, 1983 has been forwarded to me for a response. The letter contained three questions.

1. "Please explain how the test for constant molar ratios demonstrates a linear relationship between emissions and deposition." The nonlinear hypothesis predicts that the molar ratio of sulfate to nitrate in deposition should vary with distance from the major sources of emissions of SO_2 and NO_x. The prediction is a result of the different oxidation rates for SO_2 and NO_x. That is, the conversion of NO_x to nitrate is more rapid than the conversion of SO_2 to sulfate. Both conversion processes use the same oxidizing agents. The presence of NO_x, therefore, would retard the formation of sulfate if NO_x concentrations were sufficiently high or if the concentrations of oxidants were sufficiently low. Retardation of sulfate formation is the principle feature of the nonlinear hypothesis. The nonlinear hypothesis therefore predicts that the ratio of the oxidation products should be lower near source regions and higher farther away.

Data in eastern North America from regions where acid deposition is dominated by human activity do not show this type of spatial variation. Except for certain "hot spots" where the data can be understood as being dominated by local conditions, the ratio is remarkably uniform throughout the region of abnormally high acidity (pH less than about 4.6). The analysis cannot be extended to areas where the pH is typical of natural background levels (4.9 to 6.5, see page 13 of the 1983 NRC report) since the ratio in those areas cannot realistically be considered to reflect chemical transformations in the original plume of polluted air.

The spatial uniformity of the molar ratio is inconsistent with the hypothesis of nonlinearity between annual average emissions and annual average deposition. The spatial uniformity does not of itself demonstrate that the relationship is linear. Taken with other evidence that also is inconsistent with the hypothesis of nonlinearity, the NRC committee concluded that "there is no evidence for a strong nonlinearity..." Thus, within the limits of uncertainty in the data, the relationship between annual average emissions and deposition can be taken for practical purposes as essentially linear. The report does not attempt to prove that the relationship is strictly linear, since sufficient data for such a demonstration are not available.

2. "How much reduction in emissions would be needed to protect the sensitive areas from further damage?" The NRC report published in 1981 titled Atmosphere/Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion concluded that it would be necessary to reduce deposition of hydrogen ions in sensitive areas by about 50 percent if aquatic ecosystems in these areas were to be protected. According to the most recent NRC report, a 50 percent reduction in SO_2 emissions would result in roughly a 50 percent reduction in the deposition of hydrogen ions associated with sulfate (i.e., hydrogen ions in sulfuric acid). Hydrogen ions associated with sulfate account for roughly two-thirds of the total acidity (hydrogen ions) in eastern North America, with about one-third being associated with nitrate (i.e., in nitric acid). Consequently, to reduce the total deposition of hydrogen ions by roughly 50 percent, emissions of both SO_2 and NO_x would have to be reduced by roughly 50 percent. Other combinations of emission reductions might also achieve the same result, but if reductions were taken in SO_2 emission alone, very substantial reductions would be required.

I should also like to reiterate the point made during the hearings that the spatial distribution of the reductions in emisisons is important for determining whether the reduction in deposition occurs in the most sensitive areas or elsewhere. The 1983 report concluded that in the absence of quantitatively validated models for long range transport of air pollution leading to acid deposition, we cannot currently predict quantitatively with high reliability the efficacy of alternative control strategies that target the reductions nonuniformly across the region.

3. "How much reduction in emissons would be needed to reverse the decline in pH in the acidified lakes?" As pointed out in the response to question #2 (above), the conclusions of the 1981 NRC report were based on data regarding effects on aquatic ecosystems. According to that report, a 50 percent reduction in deposition of hydrogen ions is required to protect the acidified lakes.

It should also be noted that many water bodies are naturally acidic. In most cases, the acidity of natural waters is of biologic origin. Atmospheric inputs, especially of sulfuric acid, can alter the chemistry of an aquatic ecosystem from the natural one based on weak humic acids of organic origin to one based on strong acids of anthropogenic origins. It is not necessary for large changes in the pH of the water to occur when acid deposition adversely effects such lakes.

Sincerely,

Myron F. Uman
Executive Secretary

MFU/jas

cc: Jack G. Calvert

STATEMENT OF BERNARD MANOWITZ

(Before the Senate Committee on Environment and Public Works,
November 2, 1983)

My name is Bernard Manowitz. I am the Chairman of the Department of Applied Science at Brookhaven National Laboratory, Upton, NY. I am also Chairman of the National Laboratory Consortium, a group of four National Laboratories that are a Congressionally-mandated part of the Interagency Task Force on Acid Precipitation.

I have been asked by this Committee to discuss the nature and conclusions of the National Laboratory Consortium's review of the recent report on acid rain issued by the National Research Council (NRC). The review was prepared at the request of the House Committee on Science and Technology and was submitted to that Committee on August 30, 1983. I should like to expand here on my remarks of that date.

The four National Laboratories which make up the National Laboratory Consortium are Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory of Battelle. The attached documents from each of the National Laboratories provide critiques of the NRC report by individual scientists at the National Laboratories, each of whom is identified. Please note that, in each case, these comments have been reviewed internally by appropriate Laboratory authority. In sum, they therefore represent the collective opinions of the National Laboratory Consortium.

As one reviewer states, "the Committee has made a useful contribution by bringing before the public....in rather the most effective fashion to date...findings of many years of research on the transport, transformation, and deposition of airborne pollutants." Although there are many specific instances in which the Committee has brought together disparate sources of information and reached logical conclusions, the overall feeling of the National Laboratory Consortium is that the Committee's report is flawed in several areas.

A principal conclusion of the NRC Committee regards the relation between emissions of sulfur dioxide and deposition. The chairman of the NRC states in his forwarding letter that it is the "Committee's judgment that if the emissions of sulfur dioxide from all sources in this region (northeastern North America) were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition." Such a corresponding fractional reduction would be characteristic of a linear and proportional relation between emissions and deposition. The National Laboratory Consortium reviewers disagreed almost uniformly with this conclusion and with the methods used to reach this conclusion.

Specific and detailed comments on the NRC documents are contained in the reviews written by fifteen National Laboratory scientists, all of whom are active in the field.

Major points made by the reviewers were directed at two technical areas. The first relates to the interpretation of the spatial dependence of the sulfate-to-nitrate annual ratio in precipitation. The NRC report argued that this ratio is constant, and that the constancy of this ratio is indicative of proportionality in the source receptor relationship of sulfur oxides and sulfate deposition. Points raised by the reviewers are as follows:

1. Data presented on sulfate-to-nitrate ratios in precipitation and emissions show spatial patterns in North America in the same direction and of comparable magnitude as are used by the Committee itself to justify a nonlinear relationship in Europe. Moreover, even accepting a constant ratio, the conclusion of a linear removal mechanism for sulfur dioxide is not supportable. (Reviews BNL-A, PNL)
2. Details of gas phase chemical reactions and in particular the deficiencies of Rodhe's photochemical model are given more weight that can be justified in regard to a chemical-mechanistic interpretation of linearity in the atmosphere. Nonlinearities are more likely to result from pH inhibition in aqueous-phase reactions or from limitation of oxidants, topics not adequately covered in the report. (Reviews ANL, BNL-B, BNL-C, BNL-D, PNL)
3. The report concerns itself almost entirely with large spatial areas (Federal Region to sub-continent) and long averaging periods (seasonal to yearly). Averaging over such time and space scales obscures a wealth of detail that is pertinent to the mechanisms of

acid deposition. A closer look at finer spatial scales is particularly important in regard to any discussion of linearity. If large enough spatial scales and averaging periods are chosen, conservation of mass ("what goes up must come down") insures that deposition is linearly related to emissions, and, in fact, equal to emissions. Furthermore, the million-square-kilometer mixing that is discussed occurs only as an artifact of averaging over long time periods. (Reviews ANL, BNL-A, BNL-B, BNL-D)

The second technical area addressed in the National Laboratory review relates to the use of the long term record at Hubbard Brook, NH. The NRC report contends that deposition at Hubbard Brook and emissions in surrounding regions have been proportionally related over an extended period of time. Arguments raised by the National Laboratory Consortium are as follows:

4. The NRC report attempts to relate the deposition trends at Hubbard Brook to Northeastern emission trends, without appropriate confidence limits on the findings. Detailed statistical reanalysis of Hubbard Brook data, using multiple regression analysis to account for meteorological variability over the period of record as well as emission estimates for every year, finds a substantially less than 1:1 proportionality between sulfate deposition and sulfur oxide emissions. This lack of proportionality suggests a nonlinear relationship. (Reviews ANL, BNL-A, BNL-C, ORNL-A, PNL)
5. The historical records of wet deposition at Hubbard Brook, in relation to emissions trends in the Northeast, played a major role in the NRC arguments for "linearity" (and implied proportionality). Since Hubbard Brook is well outside the region of maximum emission and deposition, it is unlikely that these experimental data could reveal whether processes are linear or not. (Reviews BNL-B, PNL)
6. It seems likely that a significant proportion of the sources that affected Hubbard Brook were located in southeastern Canada; however, Canadian emissions were not included in the report's trend assessment. (Reviews ANL, BNL-A)

One final point concerns the conclusion in the NRC report that there is no evidence for substantial nonlinearity in the empirical data examined. The position of the National Laboratory Consortium reviewers may be summarized as follows:

7. A lack of evidence for nonlinearity is not logically equivalent to a proof of linearity. (Reviews BNL-C, PNL)

Despite these points of disagreement, the National Laboratory Consortium is in substantial agreement with the Committee's conclusion of the need for future research and with the priorities given. Directed field experiments, both for the purpose of determining mechanisms of acid deposition and for the purpose of establishing an improved empirical description of the source-receptor relationship, are suggested to have a first priority. Other suggestions with which we concur are the determination of source-receptor relations via atmospheric tracer and computer air parcel trajectories and the need to develop a routine monitoring method for dry deposition.

I have included both the request of the House Committee and my entire response as an Appendix to this testimony (Appendix A).

Since the time of my submission of the National Laboratory Consortium views to the House Committee on Science and Technology, Dr. Jack Calvert, Chairman of the NRC Committee, has responded to the National Laboratory Consortium review during a House Committee hearing on Sept. 13, 1983. I would like to reply here to the substance of Dr. Calvert's response.

1. Dr. Calvert disputes the statistical arguments of Reviewer BNL-A (referred to by him as reviewer D) as being seriously flawed scientifically. Dr. Calvert has submitted with his testimony comments by Professor James S. Williams, Department of Statistics, Colorado State University, Fort Collins, CO, who elaborates on the complexities of statistical analysis and makes further comments on Reviewer BNL-A's approach.

Dr. Fred Lipfert (Reviewer BNL-A) has responded to the criticisms raised by Dr. Calvert and Prof. Williams and stands by his original contention that the analysis presented in the NRC document Chapter 4 in no way establishes linearity or proportionality between emissions and deposition. Dr. Lipfert's response is attached hereto as Appendix B.

I have also arranged for an independent statistical review by Dr. Chengjun Tian, a visiting scholar in the Department of Statistics at

Columbia University. Dr. Tian also is critical of the NRC statistical approach. Dr. Tian's review is attached hereto as Appendix C.

If I may add a comment of my own, I would observe that statistical trend analyses are complex, but are also very valuable if the data are sufficient to provide statistically significant conclusions. All such analyses should be subjected to rigorous peer review before publication.

2. Dr. Calvert disputes the arguments of Reviewer PNL (referred to by him as Reviewer E) that a gradient is apparent in the sulfate to nitrate ratios in North America indicating a nonlinear process is occurring. Dr. Calvert claims that Reviewer PNL's use of Central Pennsylvania as the principal origin of a regional plume causing acid rain over North America is a distortion and that a more realistic comparison with the source region selected by the European Analysis would be the Ohio River Valley.

I have appended to this testimony a response by Dr. George Slinn, Reviewer PNL (Appendix D). Dr. Slinn makes the point that the ratio can be seen, from the data in the NRC report, to change essentially the same amount (when appropriate account is taken for both positive and negative excursions of the ratio from the appropriate mean value) regardless of the choice of origin in the Northeastern U.S.

I add my comment that if the interpretation of the sulfate-to-nitrate ratio data is sensitive to the location of the origin, then serious questions are raised as to the validity of the argument.

3. Dr. Calvert comments on the present reliability of long-range transport and transformation models. That comment will be responded to in today's testimony by Dr. Jack Shannon of Argonne National Laboratory.

4. Dr. Calvert chose not to comment to points 5, 6, and 7 raised in my letter to the House of Representatives of August 30, 1983. These points cast further doubt on the NRC Committee's hypothesis on proportionality between emissions and deposition.

In conclusion, the National Laboratory Consortium does not dispute that the relationship between emissions and acidic deposition may be proportional. We simply state that the NRC Committee's contention of proportionality is not supported by available data and must thus be judged an unproved hypothesis.

Appendix A

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD, TENN.
DOUG WALGREN, PA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
HAROLD L. VOLKMER, MO.
BILL NELSON, FLA.
STANLEY N. LUNDINE, N.Y.
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.
PAUL SIMON, ILL.
NORMAN Y. MINETA, CALIF.
RICHARD J. DURBIN, ILL.
MICHAEL A. ANDREWS, TEX.
BUDDY MAC KAY, FLA.
TIM VALENTINE, N.C.
HARRY M. REID, NEV.
ROBERT G. TORRICELLI, N.J.
FREDERICK C. BOUCHER, VA.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-637

LARRY WINN, JR., KANS.
MANUEL LUJAN, JR., N. MEX.
ROBERT S. WALKER, PA.
WILLIAM CARNEY, N.Y.
F. JAMES SENSENBRENNER, WIS.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
BILL LOWERY, CALIF.
ROD CHANDLER, WASH.
HERBERT H. BATEMAN, VA.
SHERWOOD L. BOEHLERT, N.Y.
ALFRED A. MC CANDLESS, CALIF.
TOM LEWIS, FLA.

J. H. POORE
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

August 4, 1983

Mr. Bernard Manowitz
Chairman, Department of
Applied Sciences
Brookhaven National Laboratory
Upton, NY 11973

Dear Mr. Manowitz:

The National Academy of Sciences recently released a study on acid deposition entitled "Acid Deposition: Atmospheric Processes in Eastern North America." The study was the culmination of a two year effort by the Academy to identify the critical issues concerning acid rain and the current scientific knowledge of the certainties and uncertainties of the relationship between emissions and acid deposition.

In your position as Chairman of the National Laboratory Consortium within the National Acid Precipitation Task Force, we are requesting your assistance in informing the Committee as to how the Consortium views the results stated in the report. We are particularly interested in how the stated research priorities relate to the Consortium assessments of research needs and the National Laboratories' role in conducting this research.

We look forward to receiving your comments.

Sincerely,

Marilyn Lloyd

DON FUQUA
Member of Congress

JAMES H. SCHEUER
Member of Congress

MARILYN LLOYD
Member of Congress

FSL:Jdm

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

Department of Applied Science

(516) 282 3037
FTS 666

August 30, 1983

The Honorable Don Fuqua
The Honorable James H. Scheuer
The Honorable Marilyn Lloyd
U.S. House of Representatives
Committee on Science & Technology
Suite 2321, Rayburn House Office Bldg.
Washington, DC 20515

Dear Representatives:

In response to your letter of August 4, 1983, I have asked the National Laboratory Consortium to express their views on the results stated in the National Academy of Sciences report entitled "Acid Deposition-Atmospheric Processes in Eastern North America" which was authored by an NRC Committee.

The four National Laboratories which make up the National Laboratory Consortium are Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory of Battelle. The attached documents from each of the National Laboratories provide critiques of the National Academy of Sciences report by individual scientists at the National Laboratories each of whom is identified. Please note that, in each case, these comments have been reviewed internally by appropriate Laboratory authority. In sum, they therefore represent the collected opinions of the National Laboratory Consortium.

As one reviewer states, "the Committee has made a useful contribution by bringing before the public ...in rather the most effective fashion to date... findings of many years of research on the transport, transformation, and deposition of airborne pollutants." Although there are many specific instances in which the Committee has brought together disparate sources of information and reached logical conclusions, the overall feeling of the National Laboratory Consortium is that the Committee's report is flawed in several areas.

A principal conclusion of the NRC Committee regards the relation between emissions of sulfur dioxide and deposition. The chairman of the NRC states in his forwarding letter that it is the "Committee's judgment that if the emissions of sulfur dioxide from all sources in this region (northeastern North America) were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition." The National Laboratory Consortium reviewers disagreed almost uniformly with the methods used to reach this conclusion and with the conclusion itself.

Specific and detailed comments on the NRC documents are contained in the reviews written by National Laboratory scientists, all of whom are active in the field.

Major points made by the reviewers are directed at two technical areas. The first relates to the interpretation of the spatial dependence of the sulfate-to-nitrate ratio.

- Data presented on sulfate-to-nitrate ratios in precipitation and emissions do show spatial patterns in the same direction and of the same magnitude that are used to justify a nonlinear relationship in Europe. Even accepting a constant ratio, the conclusion of a linear removal mechanism for sulfur dioxide is not supportable. (Reviews BNL-A, PNL)

- Details of gas phase chemical reactions and in particular the deficiencies of Rodhe's photochemical model are given more weight that can be justified in regard to a chemical-mechanistic interpretation of linearity in the atmosphere. Nonlinearities are more likely to result from pH inhibition in aqueous phase reactions or from oxidant limitations; topics not adequately covered. (Reviews ANL, BNL-B, BNL-C, BNL-D, PNL)

- The report concerns itself almost entirely with large spatial areas (Federal Region to sub-continent) and long averaging periods (seasonal to yearly). Averaging over such time and space scales obscures a wealth of detail that is pertinent to the mechanisms of acid deposition. A closer look at finer spatial scales is particularly important in regard to any discussion of linearity. If large enough spatial scales are chosen, conservation of mass ("what goes up must come down") insures that deposition is linearly related and, in fact, equal to emissions. Furthermore, the million-square-kilometer mixing that is discussed occurs only as an artifact of averaging over long time periods. (Reviews ANL, BNL-A, BNL-B, BNL-D)

The second technical area relates to the use of the long term record at Hubbard Brook, NH:

o The Academy report attempts to relate the deposition trends at Hubbard Brook to Northeastern emission trends in a very superficial way, without confidence limits on the findings. Detailed statistical reanalysis of Hubbard Brook data, using multiple regression analysis to account for meteorological variability over the period of record as well as emission estimates for every year, finds a substantially less than 1:1 proportionality between sulfate deposition and sulfur oxide emissions. This lack of proportionality suggests a nonlinear relationship. (Reviews ANL, BNL-A, BNL-C, ORNL-A, PNL)

o The historical records of wet deposition at Hubbard Brook, NH, in relation to emissions trends in the Northeast, plays a major role in the arguments for "linearity" (and implied proportionality). Since Hubbard Brook is well outside the region of maximum emission and deposition, it is unlikely that experimental data could reveal whether processes are linear or not. (Reviews BNL-B, PNL)

o A significant proportion of the sources that affected Hubbard Brook were probably located in southeastern Canada; yet Canadian emissions were not included in the report's trend assessment. (Reviews ANL, BNL-A)

And finally:

o A lack of evidence for nonlinearity in the empirical data examined by the Committee is not logically equivalent to a proof of linearity. (Reviews BNL-C, PNL)

On the other hand, the National Laboratory Consortium is in substantial agreement with the Committee's stated research priorities and needs. Directed field experiments, both mechanistic and data gathering, are suggested to have a first priority. The report further explains that this priority is based upon the expectation that such experiments would yield results in a shorter time than required for a molecular and dynamic description; however, laboratory and model results are needed and these activities should also proceed. Other suggestions with which we concur are the determination of source-receptor relations via atmospheric tracer and computer air parcel trajectories and the need to develop a routine monitoring method for dry deposition.

We believe that most of the Committee's assessment of research needs are incorporated in the program of the Interagency Task Force on Acid Precipitation. If that program is fully implemented, many of the uncertainties related to the most significant issues should be substantially reduced or resolved.

Sincerely,

Bernard Manowitz

Bernard Manowitz
Chairman, National Laboratory
Consortium of the Interagency Task
Force on Acid Precipitation

BM:mh
atts. 10
cc: Frank Press, Chairman, NRC
Herbert Friedman, Chairman, Comm. on Phys. Sci., Math & Res.
Jack Calvert, Chairman, NRC Comm.

Review ANL

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

Telephone 312/972-

July 26, 1983

Mr. Bernie Manowitz, Chairman
National Laboratory Consortium
Bldg. 179A, Department of Applied Science
Brookhaven National Laboratory

Dear Bernie:

The following summarizes our Atmospheric Physics Section's comments on the report entitled "Acid Deposition: Atmospheric Processes in Eastern North America", prepared by the Committee on Atmospheric Transport and Chemical Transformation for the National Research Council. Because of his broad involvement in many aspects of the National Acid Precipitation Assessment Program, most of this commentary is due to Dr. Jack Shannon, Leader of the Section's Modeling Group. Discussions have also included Dr. Marvin Wesely, Dr. In Young Lee, Dr. Romesh Kumar, and myself.

By and large, the Committee has made a useful contribution by bringing before the public--in rather the most effective fashion to date--findings of many years of research on the transport, transformation, and deposition of airborne pollutants. Nevertheless, we do have some differences of opinion relative to the Committee's conclusions, differences that are primarily matters of scale and degree. But at this stage of developing knowledge of these complex atmospheric processes, and at this point in the developing consensus for some as yet poorly defined legislative action, these differences could have far reaching consequences.

The NRC/NAS report makes a number of conclusions and recommendations which we believe are either not convincingly supported by the evidence presented, or for which we prefer alternative views supported by the evidence of our own work. These include statements such as:

1) On an annual time scale and over a 1000-km spatial scale, the formation and deposition of sulfate do not appear to be significantly nonlinear.
2) Current operational models of transport and deposition are inadequate for policy analysis.
3) Relative contributions of specific source regions to specific receptor sites are unknown.

Since each of these points deals in some way with the question of the relative "validity" of current models, it is difficult to discuss them separately. The following attempt to do so proceeds in the order presented above.

The NRC/NAS report limits its finding of "no significant nonlinearity" to the larger scales given in 1), above. Our reservations in this regard are concerned with the improved definition of these scales, specifically the determination of the shortest transport times and smallest distances below which neglecting nonlinearity could have important consequences. Time scales over which nonlinearities may affect policy should be accomodated in the design of emission control strategies. Clearly these scales are related to ecological and material effects; effects on lakes and watersheds do seem to be largely long-term--perhaps seasonal, as in snowmelt shock. But if shorter term ecological "insults" are found to be important in current research (for example, effects on vegetation at critical stages of growth), then the magnitude of time scales for nonlinearity would need reexamination.

The 1000 km spatial scale is much larger than the distances between many combinations of source and sensitive-receptor areas. The possibility of nonlinearity over shorter distances would therefore have to be considered for the consequences of potential emission control policies to be assessed accurately. Then too, even if a uniform rollback policy were adopted, all emission sources could not be uniformly reduced because of economic or equipment constraints. Instead, rollback amounts would probably be defined over some political entity of medium scale, such as a state. Current emission levels per BTU vary widely now, and some sources are much more amenable to emission control actions than others. For instance, if a plant has already installed a scrubber, little additional emission reduction could be required of that plant if it is to continue to operate. Thus, rollback could not be expected to be uniform even when totaled by state. In short, the NRC/NAS report appears to address the issue of deposition reduction by control legislation too narrowly.

We agree with the report's conclusion that nonlinearities are more likely to occur in winter, when many transformation and removal rates are slower and transport generally faster. But even this is a qualified agreement pointing up the issue of scale: specifically, over just what distances would nonlinearity be expected to limit the efficacy of rollback legislation in these--or any--weather conditions? The consequences of the interpretation of nonlinearity are too far-reaching to be based on the limited data used.

The evidence cited by the NRC/NAS report in support of their argument for linearity is a) the ~ 15-year record of weekly bulk deposition collected at Hubbard Brook, New Hampshire, b) historical SO_2/NO_x emission estimates , and c) the observed spatial patterns of molar ratios of SO_2/NO_x emissions and sulfate/nitrate wet deposition. An apparent trend of decreasing sulfate deposition at Hubbard Brook is associated with a trend of decreasing SO_2 emission in the Northeastern U.S. But there are several difficulties with this analysis:

1. No uncertainty ranges are placed on any of the emission totals. Since the SURE, MAP3S, and MOI inventories for a single year (1978) show differences in total emissions by states of 30 to 40 percent, the historical emission data used may be equally--or even more--uncertain. Such uncertainties would swamp the apparent effects of any actual emission change.

2. Trends in Canadian emissions are not considered at all; yet the Canadian contribution to bulk deposition received in central New Hampshire, i.e., at Hubbard Brook, is probably about 25 to 40 percent of the total.

3. The apparent decrease in sulfate deposition at Hubbard Brook largely results from reference to relatively high values recorded in the initial years

(approx. 1965-1969). Since that time, there appears to have been little or no further decrease in sulfate deposition, even though emission inventories over subsequent years did continue to decrease. Meteorological variability could have accounted for this deposition record, even if there had been no change in emissions; or a single, not-too-distant source operating only in the earlier years may have gone unnoticed.

4. The decrease in the molar ratio of the sulfate/nitrate bulk deposition at Hubbard Brook also seems to result primarily from a high ratio recorded in the late 1960s followed by irregularly lower values in subsequent years. The Hubbard Brook data suggests a step function rather than a trend. The possibility of analytical error--or a change in analytical technique--could be considered.

5. The NRC/NAS report does not resolve the paradox of the apparent evidence for linearity in the Hubbard Brook data and the evidence for nonlinearity in the European data. The comparison between statewide SO_2/NO_x molar emission ratios and sulfate/nitrate wet deposition ratios used to support the linear hypothesis, is not conclusive. For example, some preliminary results of modeling sensitivity tests now underway at this Laboratory suggest that the sulfate/nitrate wet deposition molar ratio is relatively insensitive to the SO_2/NO_x emission ratio; thus a decrease in SO_x emissions may not be proportionally reflected in a subsequent decrease in sulfate wet deposition.

6. The discussion concerning whether or not the Rodhe model is adequate without a chain-carrying radical to continue the reaction, glosses over the limitation imposed by the fact that both versions of the set of equations used are essentially clear-air chemistry models, and are therefore not directly relevant to wet deposition processes.

With regard to present models, we would suggest that the relative utility of many recent assessments indicates that a number of the numerical simulations now in use have been demonstrated to be adequate for policy analysis. Future improvements in modeling now proposed (and evidently advocated for future use in assessment by the NRC/NAS report) are more likely to improve diagnostic details and field experiment design than contribute directly to improvements in policy assessment exercises. Yet the report recommends against the use of current transport and deposition models for policy assessment, thus recommending , in effect, that no cost/benefit assessment be done at this critical time of legislative decision. These negative views on present modeling capability seem to be based upon the level of parameterization necessary for tractable models, and upon the Committee's perception of the results of the now outdated MOI model intercomparison.

Taking the second point first, there were many uncertainties in the 1978 SO_x emission inventory for North America used by the MOI comparison. Further, the precipitation chemistry samples used for model verification were monthly collections and were almost entirely derived from southeastern Canada. Finally, most of the models compared had only two months of 1978 meteorological data available to them. It follows that the MOI model intercomparison was hardly a rigorous test, especially in view of the improved data sets (not to mention the improved models) available today. The NRC/NAS report does concede that some present models "quantitatively point to the importance of certain geographical groupings of SO_2 sources and the potential influence of (those) sources on certain receptor areas". It can be added that some of today's parameterized models consistently reproduce, in realistic fashion, average (monthly and longer) downstream deposition patterns attributable to large groups of sources, in the form of so-called source-receptor matrices. The "ASTRAP" model developed and used at this Laboratory, for example, achieves this degree of success with objective parameterizations of mixing, transformation, and removal processes which are based on actual measurements made in ad hoc field experiments. In other words, the model has not been arbitrarily tuned to attain this performance.

This brings us to the third point of difference. On the basis of our modeling experience, we believe that average monthly and seasonal contributions of specific source regions of significant size (say, half the area of a medium sized state) to receptor regions of similar size up to 1000-1500 km downstream, can be simulated with present models sufficiently well to make objective assessments. But until the emissions from particular source regions can be identified in deposition samples, or until large scale field experiments can be performed with realistically reacting/depositing tracers, no transport/deposition model of source/receptor relationships can be rigorously verified. Present models use real fields of meteorological data, after the fact. Indeed, it is recognized that whenever possible, assessments over a certain period (month, season) should be based on models run with several years of data in order to limit the effects of meteorological anomalies. We do not believe that there is any realistic need for a truly dynamic transport and deposition model that would operate in a meteorologically predictive mode.

Even with some uncertainties in detail, analyses of proposed emission control policies based on current models are likely to be far superior to analyses of control policies without such objective consideration of the complex source/receptor relationships. Since some emission control actions may well be taken soon, it is critically important that current knowledge of transport and deposition processes, albeit imperfectly represented in today's models, be utilized in the best interests of both the public and the industry. Recommendation against the use--and, by implication, against the continued improvement of--the parameterized models, is therefore not in the national interest, particularly since the complex, 3-dimensional Eulerian grid models promised as an alternative will not be ready to simulate even a single, specific synoptic event for 2 or 3 years. Whether these complex computerized constructs will ever be sufficiently flexible--and sufficiently economical--to operate in the multiple-scenario, quick turn-around mode required for policy assesment remains to be seen. Even then, this will not be known until 3 to 5 years, hence when the new model attains a capability of simulating a statistically significant number of events.

Sincerely,

Paul Frenzen
Associate Division Director
Environmental Research Division

PF/lac
cc: J. Rundo, Associate Laboratory Director, OTD/BER
J. Roberts, Associate Laboratory Director, OTD/EE

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: August 29, 1983

TO: N. Samios, Director, BNL

FROM: B. Manowitz BM

SUBJECT: Review of National Academy of Sciences Document

In my capacity of Chairman of the National Laboratory Consortium of the Interagency Task Force on Acid Precipitation, I have been asked to review the document recently issued by the National Academy of Sciences entitled "Acid Deposition - Atmospheric Processes in Eastern North America."

I have asked four scientists in my Department to review the report. They are:

Dr. Fred Lipfert (identified as Reviewer BNL-A)
Dr. Paul Michael (identified as Reviewer BNL-B)
Dr. Lawrence I. Kleinman (identified as Reviewer BNL-C)
Dr. Stephen E. Schwartz (identified as Reviewer BNL-D)

These men were selected because of their long experience and expertise in air quality research (A), meteorological and atmospheric physics research (B), air chemistry modeling (C), and atmospheric chemistry research (D).

Their comments are substantive and critical of the broad conclusions of a 1:1 proportionality between emissions and deposition implied in the Academy report.

I concur entirely with the findings of these scientists.

pt

Review BNL-A

CRITIQUE OF CHAPTER 4 — EMPIRICAL OBSERVATIONS AND SOURCE-RECEPTOR RELATIONSHIPS

Introduction

Part of the thrust of the NAS report is that, given the present state of source-receptor modelling, we must rely on empirical observations to infer relationships between emissions and deposition and then to assess responses to mitigating strategies. One of the data sets presented for this purpose was the 16-year record of weekly wet deposition at the Hubbard Brook Experimental Forest in Central New Hampshire. While the emphasis on experimental observations may be appropriate at this time, the analysis presented was superficial and inappropriate to not only the Academy but to the importance and economics of the issue at hand.

The Hubbard Brook data have been extensively discussed and analyzed elsewhere.[1,2] But a serious attempt at a time series analysis relating these measurements to historical emissions of acid-forming precursors has not been presented, nor have quantitative relationships between wet deposition and air quality been assessed. Such a study is in progress and preliminary results are presented below.

The Academy Analysis (pp. 116-126)

The Academy analysis is based on a loose comparison of time trends between 1965-66 and 1979-80* for sulfate concentratons and emissions trends between 1965 and 1978 for any of several geographic regions. The emissions data are from the U.S. Canadian Work Group 3-B report,[3] which also reports data for two intermediate years, 1970 and 1975 (unfortunately, 1975 is a recession year and does not provide a reliable basis for trends between 1970 and 1978). Concentrations of nitrate in rain vis-a-vis NO_x emissions are also discussed, but more briefly. No statistical relationships are attempted between rain chemistry and emissions, nor are any confidence limits given for possible associations.

The trend in sulfate concentration (but not nitrate) is deduced from a linear regression analysis on 15 annual volume-weighted means, presumably giving each year equal weight. No explanation is given for excluding the two end periods, 1964-65 and 1979-80 (including them reduces the slope by about 10%). However, the trend in emissions over an equivalent period is deduced from only the two end points of the series, 1965 and 1978. The detailed behavior over the included time period is totally ignored as if the trend were monotonic (and linear) between these end points. Figure 4.15 shows that is decidedly not the case, even using the unrepresentatively low year of 1975 as a valid trend point. The fact is that 1970 (or thereabouts) is generally the peak year for SO_x emissions, after which the impact of the Clean Air Act of 1970 began to be felt. However, these reductions were realized slowly, so that the years 1968-1974 are practically flat for national SO_2 emissions. The decrease began sooner in the Northeast, about 1972. In contrast, Figure 4.14 shows an increase in $SO_4^=$ concentrations during this period. To be fair, however, it should be mentioned that a linear regression of the individual weekly samples shows an overall drop of about 20% over 15 years (discussed more extensively below).

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*Hubbard Brook publications use a "water-year," beginning in June.

In addition to using disparate analytical methods for the concentration trends vs the emissions trends, the Academy report does not deal with the question of estimating which geographic regions' emissions have the most direct impact at Hubbard Brook. By implication, the analysis points towards the nearby locations (Federal Regions I and II) and would totally exonerate Region IV, where emissions increased 33% from 1965 to 1978.

A similar process is followed for nitrate vis-a-vis NO_x emissions. Including the two end periods in a linear regression on time increases the change from +8% to +23% (increase with time). The emissions increase, calculated from only the two end points 1965 and 1978, was 8.6% for Federal Regions I and II, whereas the NO_x emissions increase for Regions I-V was 27%. Thus, the implication as to whether NO_x has an influence from areas further away than New Jersey is critically dependent on which measurement years are used at Hubbard Brook. Using all the data to determine the trend would imply that more distant source regions should be considered for NO_x (but not for SO_2), an argument that runs contrary to the discussion on sulfate/nitrate ratios in the Academy report.

The Academy report concludes, with regard to the Hubbard Brook data, that there is "no evidence for a strongly nonlinear relationship between annual depositions and annual emissions in the Northeast." As a result, elsewhere in the report, the finding is reached that a reduction in emissions would result in a proportional reduction in deposition. This implies a 1:1 relationship or an elasticity of 1.0 [a 1% change in emissions would yield a 1% change in deposition (or concentration)]. It should be clear from the data in the Academy report that this finding is not supported, even with the limited analysis presented.

For sulfate concentrations, the following elasticities result from the Academy analysis, depending on the region of SO_2 emissions to be controlled:

Region I	1.15
Regions I and II	1.18
Regions I and II and III	0.67
Regions I - V	0.25

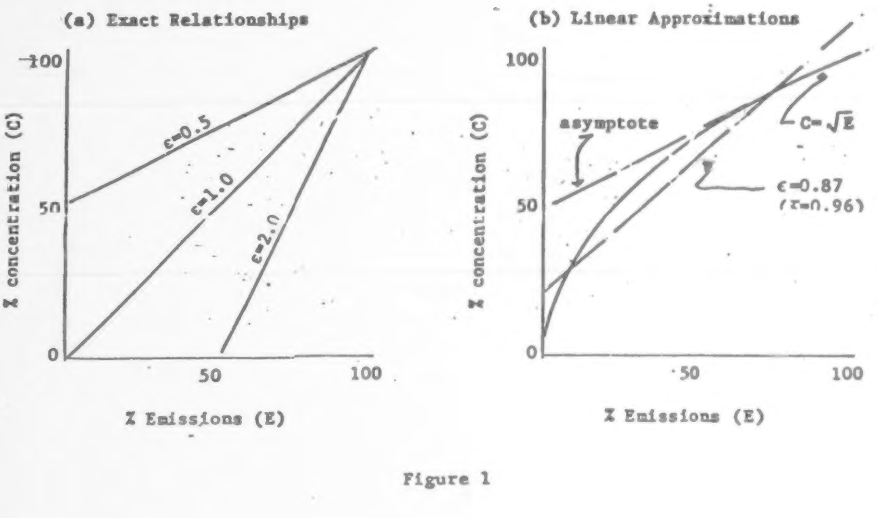
Thus, given the uncertainties of the analysis, the linear (i.e., proportional) hypothesis is supported if only the emissions from Regions I and II are considered for control, but not if Regions further south and west are included. The bulk of the report (and most of the extant literature on source-receptor relationships) makes it clear that such more distant regions should in fact be considered.

To illustrate the relationship between elasticities (as deduced from linear regressions) and hypothetical non-linear relationships, consider Figure 1:

Figure 1(a) shows three linear relationships with differing elasticities. The proportional relationship, $\epsilon = 1.0$, yields a 50% reduction in concentration (or deposition) for a 50% change in emissions. However, if $\epsilon = 0.5$, only half the benefit is realized due to the presence of a y-intercept which could represent deposition arising from natural background or from sources outside the region of consideration. Converse arguments hold for $\epsilon = 2.0$.

Figure 1(b) shows how an actual non-linear relationship ($C = \sqrt{E}$) might be represented by linear approximation, for example derived from regression analysis. A linear regression through the entire curve (11 points spaced every 10% in emissions) yields a correlation coefficient of about 0.96, explaining 92% of the variance (which would be considered an excellent fit). The slope (and hence elasticity of this line is 0.87, which is not very different from unity. Yet if reductions in emissions are postulated of the order of 50%, the asymptotic linear approximation shows that only about half of the expected benefit would be realized in fact. It should be noted that in most cases, we are working with the upper ends of the curves in question (the range in National SO_x emissions from 1965 to 1979 is about 5 million tons out of a total of about 30 million.

It should be clear from this example that it is extremely unlikely that statistical analysis of time trends will be able to detect nonlinearities per se. However, differences in the elasticities of linear best-fit relationships should indicate the degree of proportionality to be expected. The range of elasticities given above, based on the figures in the Academy report, indicate that no conclusions on linearity or proportionality can be made from this analysis.


(a) Exact Relationships

(b) Linear Approximations

Figure 1

Reanalysis of the Hubbard Brook Precipitation Chemistry Data (1964-79)

Because of the importance of this data set, a reanalysis of the weekly (bulk) samples has been carried out, using multiple linear regression methods. The dependent variables were the amounts of precipitation in each weekly sample and concentrations ($\mu eq/\ell$) of the following ions: H^+, $SO_4^=$, NO_3^-, Cl^-, Al^{+++}, NH_4^+, Ca^{++}, Mg^{++}, K^+, SiO_2, $PO_4^{\equiv}$ and Na^+. Concentrations were corrected for sea salt content assuming that all the sodium is derived from that source. Further, the balance between positive and negative ions was calculated, and only the observations for which this balance was achieved within ±20% were retained (about 87% of the observations or about 440 values).

The following independent meteorological variables were used:

PRECIP — the amount of each weekly sample

WAVE — a periodic function intended to be a surrogate for such seasonal effects as photoperiod, wind trajectory variations, fraction of convective vs continuous storm, etc.

$$\text{WAVE} = \cos\left[\left(\frac{\text{day of year}}{365} \times 360\right) - 180 * \frac{\pi}{180}\right]$$

MAVTEMP — monthly average surface temperature at Concord, NH (finer time resolution not readily available).

The influence of trajectory differences by year at Hubbard Brook was considered in detail by Munn et al.[2] SO_4 concentrations were normalized by accounting for the frequency of occurrence of 5 different wind direction sectors; concentrations tended to be higher for trajectories originating to the south and west of Hubbard Brook than from the east, for example. However, this normalization had only a trivial effect on the actual annual median SO_4 concentrations, increasing the overall mean about 1-3%, but with virtually no change in the standard deviation from year-to-year. Thus, by implication, the differences shown from year-to-year in median sulfate concentration are not due to trajectory variations. The assumption that this source of variation may be ignored in a multiple regression analysis without creating bias appears to be well-founded.

The emissions data were computed for each year from 1964 to 1979 based primarily on fuel use data[4] at the state level for the United States. Statewide fuel sulfur contents were derived from FPC Form 67 data from 1969 to 1976. For years prior to 1969, these values were assumed constant. For years after 1976, emissions by state were estimated from published EPA reports. In general, this approach captures only combustion-derived emissions, a limitation that is not believed to be serious for the Eastern United States. Canadian copper-nickel smelter emissions[5] were also included for these years, as was an estimate of other eastern Canadian emissions,[6] for which only 2 years' data were available requiring linear interpolation to represent the 16-year period.

Quarterly shares of emissions were available for 2 years (1965 and 1978),[9] for the SURE region (Northeastern U.S.). The differences between these shares and a uniform annual distribution were minor, with higher emissions in the winter. When used, these quarterly shares were applied to all emissions estimates, regardless of geographic region. A conservative estimate of the number of degrees of freedom for the emissions data is then 18 (16 annual values plus 2 quarterly shares). Comparison of these independent emissions estimates with those of EPA shows somewhat higher estimates but similar trends (for the years available from EPA).

As an alternative to aggregation by summation, weighting schemes were considered in order to combine emissions from the various geographic regions thought to have an influence at Hubbard Brook. Both inverse linear and inverse squared weightings were used, based on distances from Hubbard Brook to the estimated emissions centroids of the regions.

Multiple linear regressions were performed, using the stepwise mode and the meteorological variables listed above together with various emissions variables. The regression step selected for detailed consideration was either the one with the lowest standard error of estimate (highest adjusted R^2) or the subsequent step upon which the emissions variables entered the regression. Examination of residuals did not indicate autocorrelation to be significant, based on the Durbin-Watson statistic.

It was hypothesized that sulfate deposition at Hubbard Brook derived from two separate sources: aerosol which had been scavenged by precipitation, and sulfate formed in clouds. The aerosol portion was proportional to the concentration of ammonium ion (NH_4^+) in precipitation. Thus, the balance ($SO_{4eq}^= - NH_{4eq}^+$) would be a surrogate for the sulfate formed in clouds. An alternative estimate of in-cloud sulfate subtracted the calcium equivalent in addition ($SO_{4eq}^= - NH_{4eq}^+ - Ca_{eq}^{++}$), recognizing that calcium is an important ion at Hubbard Brook, with a substantial downward time trend. However, since calcium is thought to be derived from suspended dust of coarser particle size that ammonium (sulfate), these two ions were not summed to represent aerosol derived from anthropogenic emission sources.

Table 1
Elasticities and 95% Confidence Limits

Relationship	Emissions Region	Summed Emissions	Linear Weighting	Squared Weighting
NO_3^- vs NO_x	State of NH	0.75±0.36	—	—
	Region I	0.25±0.45	—	—
	Regions I - II	0.70±0.85	0.89±0.62	0.70±0.51
	Regions I - III	1.41±0.58	1.17±0.69	0.84±0.56
	Eastern North America	1.12±0.61	1.03±0.57	0.88±0.51
	All U.S. + E. Canada	0.89±0.45	0.88±0.47	0.84±0.47
$SO_4^=$ vs SO_2	State of NH	0.05±0.30	—	—
	Region I	−0.27±0.44	—	—
	Regions I - II	−0.59±0.62	0.20±0.23	0.20±0.22
	Regions I - III	−0.42±0.84	0.30±0.32	0.24±0.26
	Eastern North America	−0.22±0.88	0.39±0.37	0.31±0.33
	All U.S. + E. Canada	0.52±1.00	0.59±0.71	±0.42±0.46
NH_4^+ vs SO_2	State of NH	0.60±0.52	—	—
	Region I	0.47±0.35	—	—
	Regions I - II	0.55±0.43	0.53±0.40	0.51±0.38
	Regions I - III	1.01±0.68	0.81±0.56	0.63±0.46
	Eastern North America	1.00±0.67	0.96±0.65	0.81±0.57
	All U.S. + E. Canada	2.77±1.70	1.94±1.19	1.18±0.77
($SO_4^=$ - NH_4^+) vs SO_2	State of NH	−0.11±0.33	—	—
	Region I	−0.49±0.48	—	—
	Regions I - II	−0.91±0.68	0.11±0.26	0.10±0.24
	Regions I - III	−0.93±0.92	0.15±0.36	0.12±0.29
	Eastern North America	−0.73±0.96	0.21±0.42	0.17±0.37
	All U.S. + E. Canada	0.13±1.10	0.20±0.77	0.20±0.50

Table 1 presents preliminary results from this analysis, based on the following:

- Only data for which an ion balance was achieved within ±20% were retained.
- Annual rather than quarterly emissions were used (elasticities are slightly lower and less statistically significant when the quarterly values are used).
- 95% confidence limits are based on 15 degrees of freedom ($t = 2.13$).
- Emissions are aggregated by Federal region in three different ways: summation, weighting by the inverse distance from Hubbard Brook to the estimated centroid of emission, and weighting by the square of that distance.

Nitrate Ion

Statistically significant relationships were shown for almost all cases. In most cases, the elasticities are not significantly different from unity. There is no reliable indication as to which emission region provides the best fit, but there does seem to be a tendency towards an area larger than Federal Regions I and II.

Sulfate Ion

There are no statistically significant relationships between sulfate in rain at Hubbard Brook and SO_2 emissions for any of the regions considered. However, the weighted "all U.S. + Canada" cases nearly achieved significance with an elasticity around 0.5 (most likely value).

Ammonium Ion

Ammonium ion (taken here as a surrogate for sulfate derived from aerosol) shows statistically significant relationships with SO_2 emissions in all cases. Moreover, as the region increases in size, the elasticity increases, indicating a possible need to control over a wide region for maximum effectiveness. However, as with nitrate ion, it is not possible to indicate the optimum region for control with any degree of confidence.

Sulfate Less Ammonium

The difference between sulfate and ammonium equivalents is interpreted here as a surrogate for sulfate formed in clouds. No positive statistically significant relationships are seen. Since it is difficult to conceive of a physically meaningful negative relationship, the weighted results appear to be the most credible and indicate no relationship between the two variables. This could indicate a situation of saturation, in which no more sulfate is formed if fresh SO_2 is supplied, and no less if SO_2 is reduced. Such a situation can only pertain locally, due to global mass balance considerations. Subtracting calcium in addition to ammonium ion did not materially change these results.

Figures 2 to 5 present plots of "seasonally adjusted" annual mean concentrations vs emissions. The "seasonal adjustment" procedure accounts for the effects of precipitation amount, monthly average temperature, and the seasonal periodic function (WAVE) by subtracting these effects as predicted by the regression equation, according to the following formula:

$$C_{seas.adj.} = C_{measured} - (K_1 * PRECIP + K_2 * WAVE + K_3 * MAVTEMP)$$

where the K's are given by the averages of coefficients for several regression equations.

Figure 2 presents the time trends for sulfate in precipitation at Hubbard Brook and for the linearly (inverse) weighted SO_2 emission parameter, which includes all of the U.S. and Eastern Canada. After 1970, the trends are reasonably concordant, but before 1970 they are opposing. The $SO_4^=$ plot looks much like Fig. 4.14 in the Academy report, even though weighting by precipitation volume has not been done in Figs. 2-5.

Figure 3 presents the cross plot, which indicates a weak (non-significant) positive relationship between the two parameters, with an elasticity of 0.35. An elasticity 1.0 line is also shown for comparison, and the two years used in the Academy report (1965 and 1978) are flagged. Note the very different impression created by considering just these two years.

Figure 4 presents a similar plot for ammonium ion, but in sharp contrast the data fit an elasticity $\simeq$ 1.0 line with a highly significant correlation ($P < 1\%$). Figure 5 presents nitrate data vs the linearly weighted (inverse) NO_x emission parameter, which also results in a highly significant correlation, but a lower elasticity than obtained with the weekly sample analysis. The use of only 1965 and 1978 would provide a reasonable estimate in this case.

Conclusion

This analysis has indicated that at Hubbard Brook, proportional reduction might be expected in nitrate and ammonium deposition from the control of NO_x and SO_2 emissions, respectively. Considerably smaller benefits if any, would be expected for deposition of sulfate ion.

Figure 2. Time Trends for SO_2 Emissions and Precipitation Sulfate

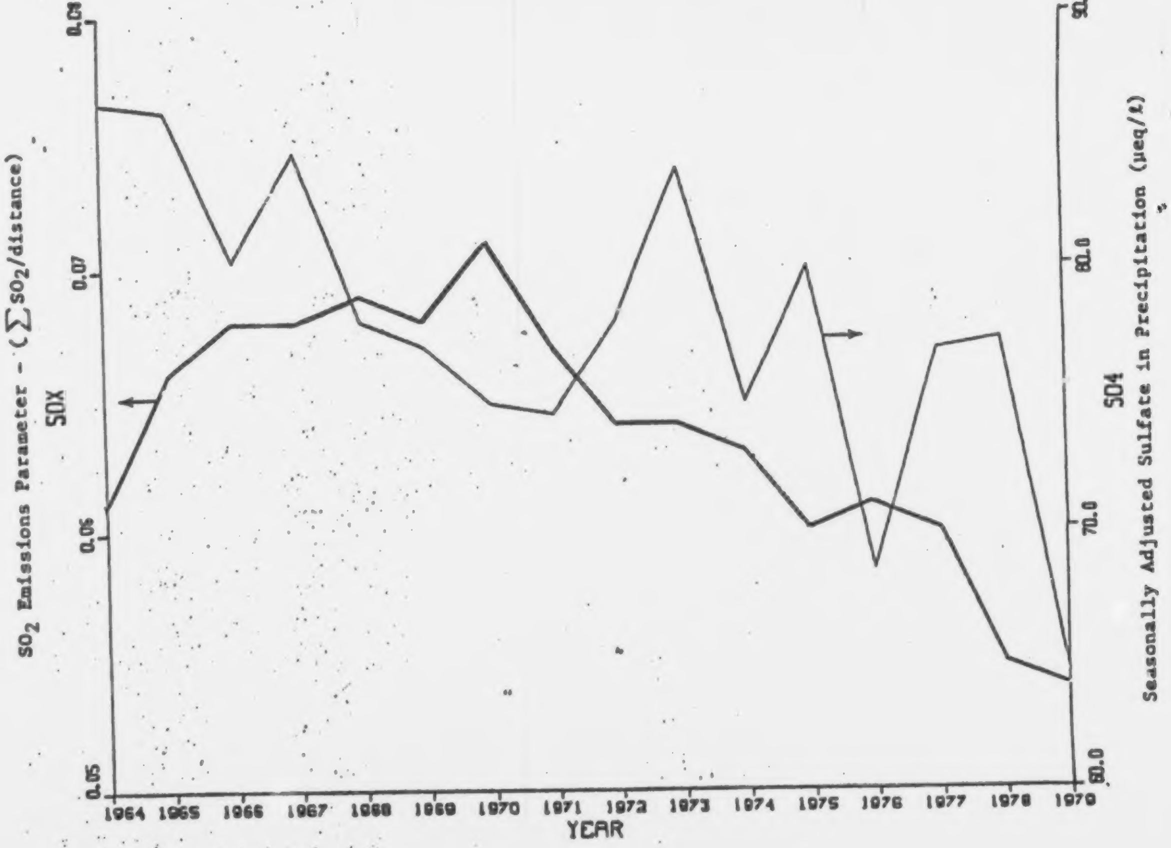


Figure 3. $SO_4^=$ vs SO_2 Emissions
(annual means)

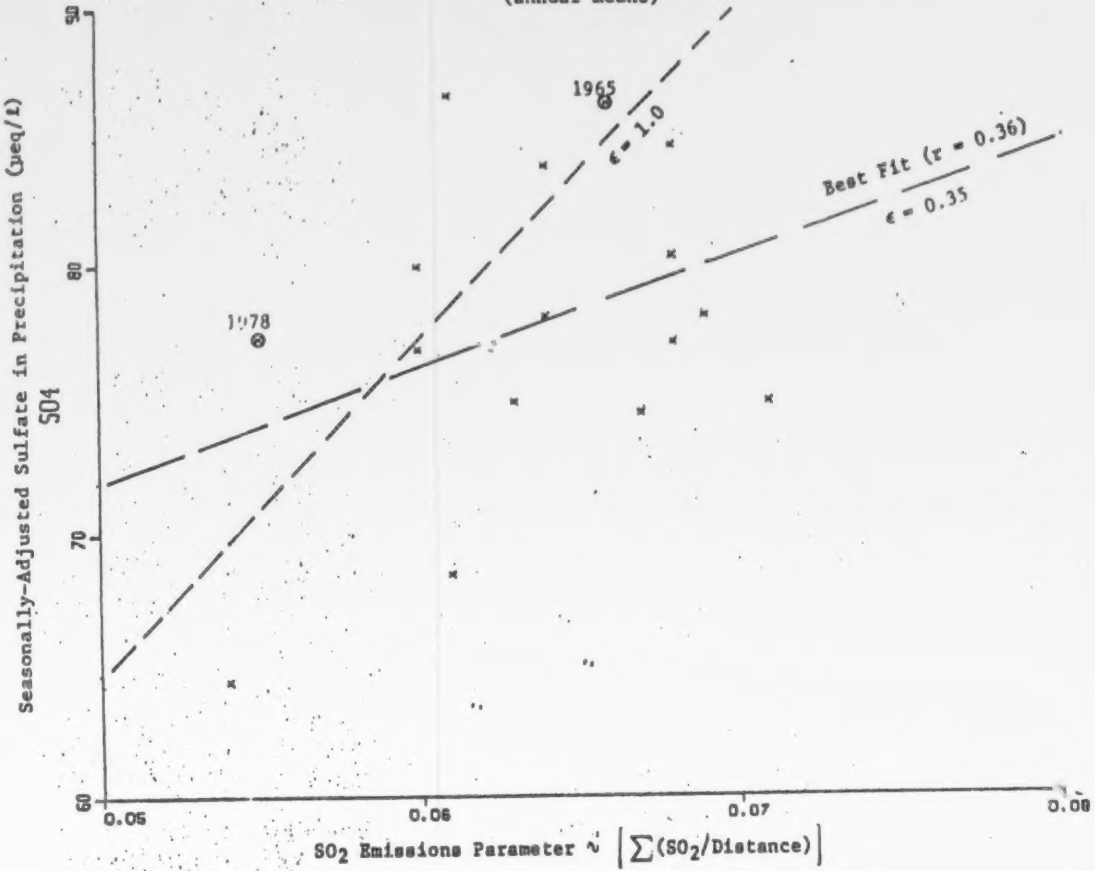


Figure 4. NH_4^+ vs SO_2 Emissions
(annual means)

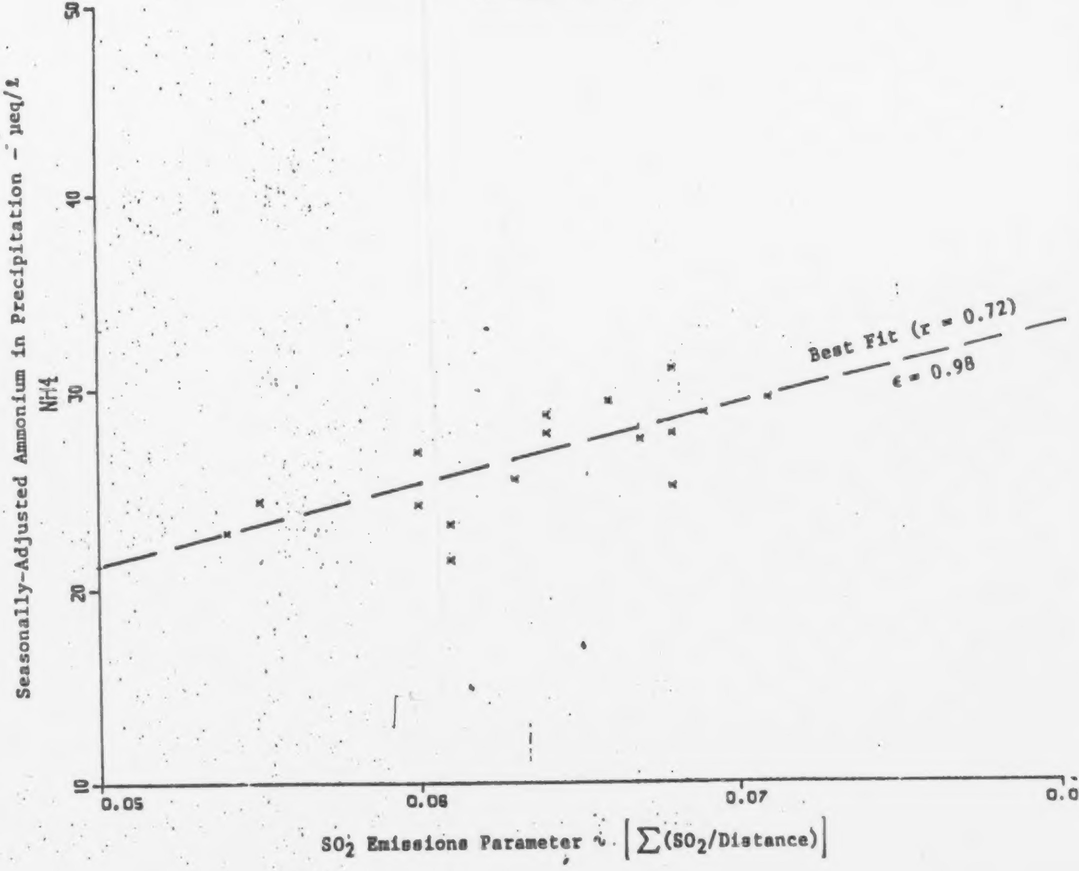
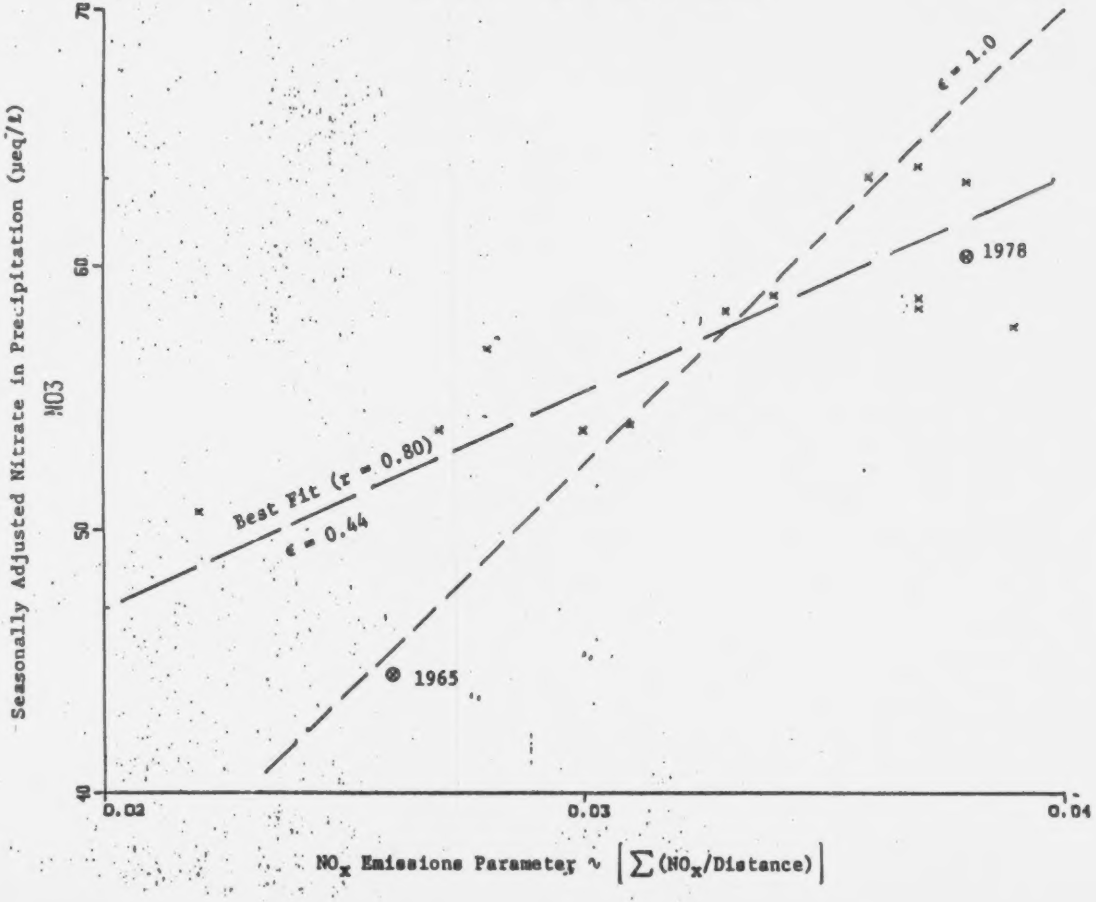


Figure 5. NO_3^- vs NO_x Emissions



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2. R.E. Munn et al., "A Climatological Analysis of the Hubbard Brook (NH) Precipitation Chemistry Data," Final Report to the U.S. Department of Energy, University of Toronto, Nov. 30, 1982.

3. Work Group 3B (Emissions, Costs, and Engineering Assessment), U.S.-Canada Memorandum of Intent on Transboundary Air Pollution, Final Report, June 1982.

4. U.S. Department of Energy, Energy Information Administration, Federal Energy Data System Statistical Summary Update, DOE/EIA-0192, July 1979.

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6. Frank Vena, personal communication, Sept. 28, 1982.

Sulfate-to-Nitrate Ratios

The Academy report compares North American to European data for the molar ratio of (wet) deposited sulfate to nitrate in relation to the ratio of emissions, and argues that the greater uniformity of this deposition ratio in North America indicates the absence of nonlinearities in sulfate deposition processes, in contrast to the European situation.

What the report does not address in this regard, however, is the spatial distribution of the ratio of sulfur to nitrogen oxide emissions in relation to the ratio of deposition. The emissions ratio in Europe is not even mentioned (it is much higher than in the U.S.). This critique will attempt to develop these more detailed insights, for the U.S. situation, in order to test whether the Academy report's conclusions are still valid on a more detailed scale. The primary parameter to be examined is the "ratio of ratios," i.e., the molar ratio of sulfur-to-nitrogen wet deposition divided by the molar ratio of SO_2 to NO_x emissions.

Both spatial and temporal distributions are considered. For the spatial distribution, published deposition data are compared to the emissions data given in the Academy report. For the temporal distribution, the weekly samples at Hubbard Brook are compared to a year-to-year historical emissions data base which has been developed for that purpose (unpublished data).

In comparing Europe to North America, it must be remembered that almost all of the strong European sources are far from the regions where deposited sulfate begins to overwhelm deposited nitrate. In contrast, in North America, the source region is considerably larger and more varied in emission make-up. In the midwest, industrial SO_2 sources predominate, whereas in the east where fuel sulfur is strictly controlled, NO_x (transportation, home heating, etc.) reflects the higher population densities. Northern Canada should compare to Northern Scandinavia, however.

Spatial Distributions

Comparing Pack's[1] concentration isopleths to the emissions distributions in the Academy report (Fig. 4.18) we can look at the spatial distribution of $SO_4^=/NO_3^-$ in relation to emissions (SO_2/NO_x in molar units), rather than just in some undefined "region." For this purpose, transects were drawn along the estimated major and minor axes of the elliptical deposition isopleths, with peaks for both $SO_4^=$ and NO_3^- assumed to occur roughly at Steubenville, Ohio. Emissions ratios were plotted near the centroids of states, except for Illinois and Missouri which were averaged and taken at St. Louis in order to smooth the distribution.

Along the east-west transect, emission ratios show much more variation than the deposition ratios. The big emitting states have emissions ratios from 1.0 to 1.87, generally higher in the western portion of the transect. Deposition ratios are higher there also, decreasing to about 1.0 at the eastern boundary. If the deposition ratio is compared to the emissions ratio at the same location, the ratio of $SO_4^=/NO_3^-$ deposited to that emitted is of the order of 0.6-0.7 in the source region, rising to 1.8 at the eastern boundary. Thus it is apparent that in the midwest, sulfate deposition is inhibited relative to nitrate and is transported to the east to be deposited there.

This point is even more obvious if a perpendicular transect is taken (generally) south from Steubenville to North Carolina. The deposition ratio remains at 1.1-1.3 almost all the way (there is an anomaly at the 30 μm/ℓ $SO_4^=$ isopleth), whereas the emissions ratio in Virginia and North Carolina is at about 0.7. Since prevailing winds (if there is such a thing) are generally west-to-east, it may be prudent to translate the emissions transect to the west of the deposition transect to which it is to be compared. A distance of about 650 km was (arbitrarily) chosen for this purpose. On this basis, along the north-south transect, the ratio of $SO_4^=/NO_3$ deposited to that emitted 650 km to the west varies from about 0.6 to about 0.85, again with the lowest values in the source region reflecting a saturation condition. Going back to the east-west transect with a westward displacement of 650 km for emissions, we find a situation very similar to the south transect: ratios of $SO_4^=/NO_3^-$ deposited to emitted of 0.6 to 0.7 with the 0.7 value at the east coast. These data are plotted in Figure 1.

For a northern transect, it is necessary to use Canadian data, as for example shown by Semonin[2] as sulfate and nitrate deposition averages (mg/m^2) for combined CANSAP and NADP network data (monthly averages). The peak is shifted slightly to the north compared to Pack's data, but again, NO_3^- and $SO_4^=$ peaks roughly coincide. The molar ratio of deposition is about 1.0 in this peak region and begins to rise at about the location of the Sudbury smelters, reaching values of about 2.0-2.4 about 1100 km to the north. This trend is quite comparable to the European data shown in the Academy report.* Note that the very large SO_2 emissions from Sudbury are not felt immediately as increased wet deposition, especially not to the South** where NO_x emissions are highest. The emissions map (Fig. 4.18) indicates that in most of the Northern Canadian areas, sulfate should totally overwhelm nitrate (emissions ratios from 6.51 to 67.56), yet the deposition ratios do not differ greatly from the east-west transect in the U.S. (for coincident emissions and deposition). Deriving appropriate emissions ratios for this transect in Canada is thus quite difficult without recourse to meteorological models showing dominant storm tracks, in part because of the presence of numerous large water bodies to the south and west. Nevertheless, there is poor correspondence between deposition and emission ratios, indicating suppression of sulfate deposition.

A southwest-northeast transect into Atlantic Canada might be more appropriate than the previous due north transect. Similar results are seen by comparing emissions and deposition ratios in New Brunswick and Newfoundland (about 800 km apart), for example, as shown below.

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*It should be noted that if we are to rely on the spatial distribution of the European data, we should also rely on the temporal trends (which had been discounted in the Academy report).

**The perturbation in the N S transect curve in Fig. 1 at 500 km may reflect the presence of Sudbury, but the emissions ratio there is about 67, leading to a "ratio of ratios" of ~0 if non-coincident emissions are used.

	Deposition $SO_4^{=}/NO_3^{-}$	Emissions SO_2/NO_2	Dep/Emissions (Coincident)	Dep/emis. shifted NE
New Brunswick	1.61	2.62	0.61	
Newfoundland	1.95	1.51	1.38	0.74

Comparison on a coincident basis shows depression of sulfate deposition, which is reflected further downwind in Newfoundland as increased sulfate deposition. Comparing Newfoundland deposition to New Brunswick emissions (last column) shows sulfate deposition to be depressed, just as was shown in the U.S.

Returning to the Academy report, a presentation is made of the North-South gradient in deposited sulfate/nitrate ratio in Europe (1.1-2.0 below about 63° latitude rising to 5.7 in the far north), but no mention is made of the emissions ratio there. For the 11 countries (all in Western Europe) participating in the OECD Long Range Transport Study,[3] the ratio was 1.88. There is some reason to believe it could be even higher in eastern Europe, where high sulfur fuels are used and transportation sources of NO_x are less important. Thus, in Europe as well as North America, SO_4 deposition is inhibited relative to nitrate near source regions, resulting in excess sulfate deposition in more remote regions.

One final note: sulfate/nitrate deposition ratios tend to be elevated in urban areas, primarily because of higher sulfate in the winter than in rural areas, reflecting local source effects. (In general, nitrate deposition is not elevated in urban areas. Thus, in making spatial comparisons, the influence of urban areas must be excluded. It is also possible that this phenomenon reflects differing urban atmospheric chemistry as well, for example, the inhibition of ozone formation by local NO_x sources.

Temporal Trends

Thus far we have invoked only spatial trends to examine the sulfate/nitrate ratio question. Temporal trends can be invoked as well, since in general NO_x emissions have been rising, whereas after 1970, SO_2 emissions have generally declined. The Hubbard Brook precipitation chemistry data provide a sufficient record for this purpose.

First of all, there is a difference between the mean of the sulfate/nitrate concentration ratios and the ratio of the means (1.25 vs 1.06), reflecting a skewed distribution as well as correlation between sulfate and nitrate concentrations.* Since atmospheric chemistry acts on individual events and not on the means, the entire preceding discussion may be hopelessly clouded by the use of long term deposition averages.

Regression analysis was performed on the concentration ratios vs meteorological and various emission ratios (for successively larger regions), for years after 1965.* The only meteorological variables of significance were the monthly average temperature and the seasonal periodic function, both indicating an increase in the SO_4/NO_3 ratio in summer. The emissions ratio, was most significant when averaged over Federal Regions I and II, with an elasticity of 0.43 ± 0.35. When larger regions were used, elasticities increased somewhat, but statistical significance dropped. Correlations were quite modest; only about 15-16% of the variance in weekly samples was explained. The fact that elasticities were significantly less than unity is further indication of lack of strict proportionality between emissions and deposition. Thus, based on sulfate/nitrate ratios at Hubbard Brook, there is no assurance that a change in emissions ratio would be reflected in a proportional change in deposition ratio.

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*This figure is based on the years from 1966 onward; in 1964 and 1965, there were a number of low nitrate readings leading to sulfate/nitrate ratios as high as 120. However, Hubbard Brook personnel stand by the data as recorded.[4]

Conclusions

The Academy report concludes that sulfur and nitrogen atmospheric and deposition processes are quantitatively similar since both emissions and deposition ratios are about 1.0 when averaged over a large region. They invoke a comparison to the European deposition ratio distribution to show that Europe and North America display different atmospheric chemistry situations.

This review has shown that in North America, sulfur deposition is depressed relative to nitrogen in source regions, rising to show an excess in more remote (or lower emissions density) regions. The Academy's use of regional averages obscures this fact. This depression of sulfur deposition may indicate a saturation phenomena in regions of large sulfur emissions, which would constitute a significant non-linearity in the system. In addition, when the European sulfur-to-nitrogen emissions ratio is considered, no important differences appear between the two continents.

Thus, in contrast to the Academy's findings, the data on sulfur/nitrogen ratios support the presence of significant non-linearities in the system, which would result in a disproportional relationship between changes in emissions and changes in deposition.

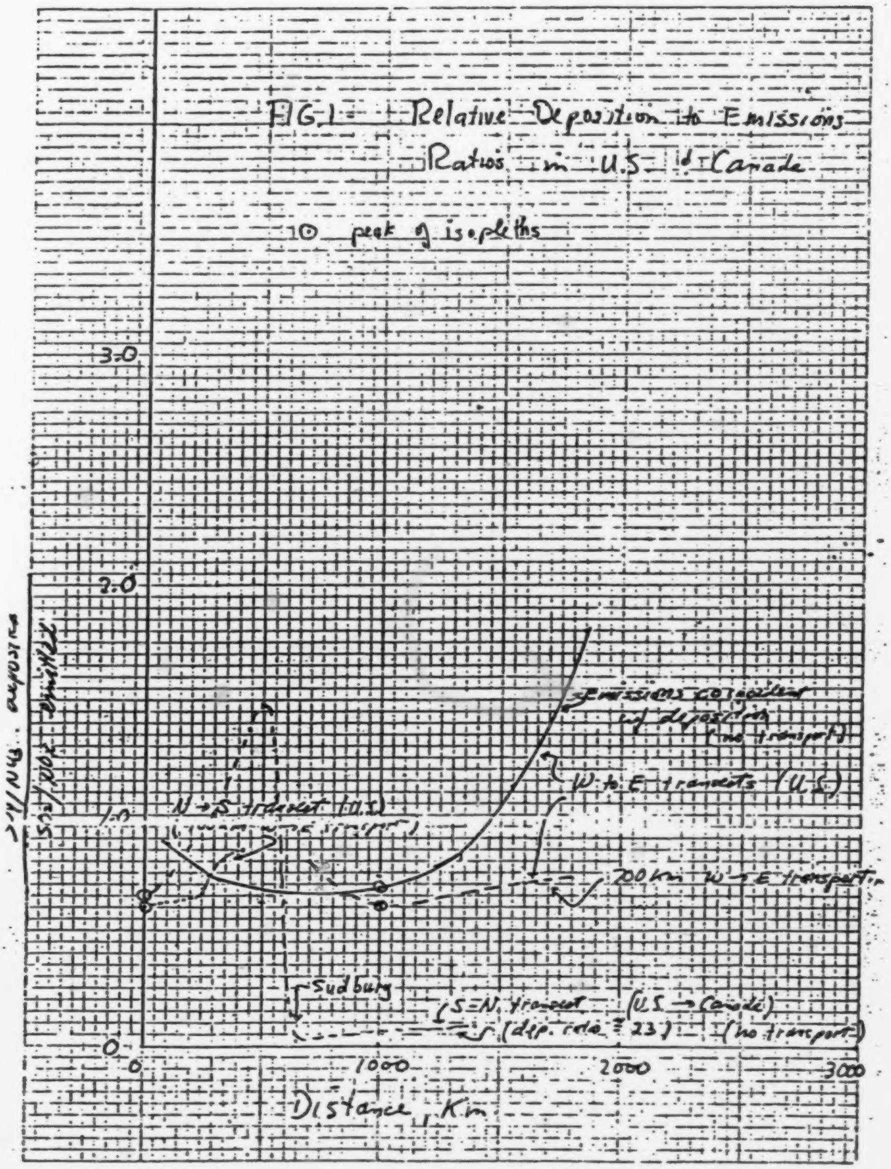

FIG. 1 – Relative Deposition to Emissions Ratios in U.S. & Canada

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2. Semonin, R.G. "Seasonal Precipitation Concentrations and Depositions for North America from the CANSAP/NADP Networks," AIAA 82-0334, January 1982.

3. Organization for Economic Co-Operation and Development. The OECD Programme on Long Range Transport of Air Pollutants, Measurements and Findings, Paris, 1977.

4. Likens, G.E., personal communication, Aug. 1, 1983.

Review BNL-B

The Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation of the National Academy of Sciences in their recent report state that "there is no evidence for a strong nonlinearity between long-term average emissions and deposition," (Summary page 7). They admit that the conclusion is clouded by uncertainty (p. 9) due to "the limited amount and uncertain quality of the data, the natural variability of atmospheric processes, and the lack of firm understanding of the physical and chemical processes involved." Beyond these disclaimers, there are a number of questions that can be raised concerning the basis for the NAS conclusions. These points need resolution before the conclusions are used for the setting of emission control policies.

1. ONLY WIDE-AREA, LONG-TERM CONCLUSIONS ARE DRAWN

The NAS committee looked at long-term data only; they did not address the short-term (event) or the spatial scale of less than a few hundred kilometers. The million-square kilometer so-called mixing that they discuss occurs only as an artifact of averaging over long time periods.

On the other hand, it is, no doubt, true that if a large enough area is considered, the acid deposition response to emissions will be linear. The real question is "On what scale is the system linear?"

2. THE USE OF HUBBARD BROOK DATA IS QUESTIONABLE

The deposition concentrations at Hubbard Brook are somewhat lower than those in the region of highest concentrations (by almost a factor of two).

The very nature of mechanisms that can cause nonlinearities (i.e., limited amounts of oxidant, competition among species, pH-induced limitations on mass transfer, etc.) means that, at first approximation, the effect will be most evident where the concentrations are the highest. However, because of the fact that the system will appear linear if averaged over a large enough region, an opposite effect is liable to be seen where lower concentrations occur far downwind of the high source and concentration regions. For example, a lack of sufficient oxidant in a region would allow unoxidized SO_2 to be vented from a storm and made available farther downwind. Hence, an increase (or decrease) in emissions might result in a smaller than proportional increase (or decrease) in concentrations near the regions of high emissions; thus, a proportionally greater (or lesser) amount of unreacted primary pollutant will be available to be deposited downstream. Following this line of reasoning, it is quite possible that Hubbard Brook could be in a location where ambiquous results on linearity would be obtained. The attached figure illustrates the point.

3. INSUFFICIENT ATTENTION IS GIVEN TO IN-CLOUD CHEMICAL REACTIONS AS A POSSIBLE SOURCE OF NONLINEARITY.

There is a large amount of admittedly inferential evidence that a major portion of precipitation acidity derives from in-cloud oxidation. Quite a number of authors have put forth this point of view (Newman, 1979; Scott, 1982; Lazrus, et al, 1983; Oppenheimer, 1983; etc.). Hence, the effort to discredit the model of Rodhe, et al, (1981) might well be moot; the Rodhe treatment of in-cloud oxidation is quite simplified and does not seem to have been improved in the calculations reported in the NAS report. The report discusses how H_2O_2 production might be suppressed in a NO-rich polluted atmosphere and how it could be rained out early in a storm leaving unreacted SO_2. They recognize that this could be the source of nonlinearities, but note the lack of an adequate data base to test the possibility. The report states that the data "suggest that concentrations of (oxidant in cloud water) may be sufficient in eastern North America for complete oxidation of SO_2 except, perhaps, in winter." There are a number of photochemical calculations that would indicate that the H_2O_2 concentrations are several times too low. At best, the point is arguable; it might just be that the NAS report is incorrect.

4. "LACK OF EVIDENCE FOR STRONG NONLINEARITIES" IS NOT A PROOF OF LINEARITY.

Stating that "no evidence of strong linearity" could be found is far from being a logically sound proof of linearity.

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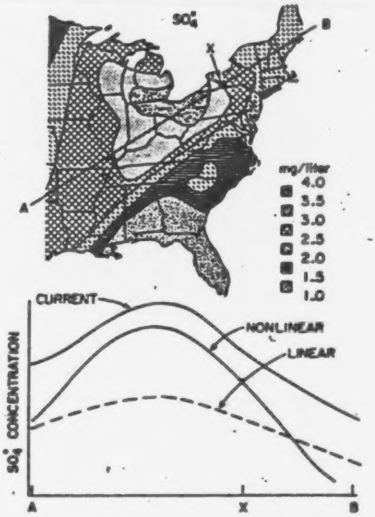
SO$_4^=$
B
X
A
mg/liter
4.0
3.5
3.0
2.5
2.0
1.5
1.0
CURRENT
NONLINEAR
LINEAR
SO$_4^=$ CONCENTRATION
A
X
B

Fig. 1. Top--Observed 1979 average concentration of SO$_4^=$ in precipitation (after Wilson and Mohnen, 1982). Bottom--Current concentration along cross section A-B and hypothetical concentrations that would result from an emission reduction if the response were linear or nonlinear.

Review BNL-C

Comments on "Acid Deposition - Atmospheric Processes in Eastern North America - A Review of Current Scientific Understanding," National Research Council.

Three major issues are considered and appear to serve as foci for the material reviewed in the report. As stated on pages 6-9, these issues are (1) "applicability of models to decisions on control strategies," (2) "nonlinearity" and, (3) "influences of local and distant sources."

I. Models:

The authors have applied a healthy degree of skepticism and insight in arriving at their conclusions regarding the usefulness of models. To paraphrase the report (pp 148-149) ..... a great deal of research is required before the acid deposition problem can be described with precision by models. It is fairly clear that in this statement the usefulness of models is judged relative to the needs of policy makers, not to the needs of research scientists. The use of models, even complicated ones, by the latter group, should be judged by different standards. Although models cannot be used to make a priori predictions of many of the important features of the acid deposition problem, they can be used to good advantage by the research community in designing experiments, interpreting data, performing controlled computer experiments on the environment and, in general, increasing our understanding of how the various pieces of a complex problem interact with each other.

II. Nonlinearity:

An unsupported conclusion is reached regarding the relation between emissions and deposition. "It is .... improbable that the oxidation of SO_2 is sufficiently hindered by a lack of oxidant to cause a disproportionately small reduction in sulfate concentrations as a result of a given reduction in SO_2 emissions." (p 9). The "evidence" in the text for this statement derives from a comparison of deposition at Hubbard Brook with emission, from consideration of the gas phase oxidation chemistry of SO_2 and from the sulfate to nitrate molar ratio in precipitation as compared with emissions. This evidence, some of which can be interpreted in different ways, as described below, does not support the stated conclusion that deposition is linearly related to emissions. At best, one could say, "Direct evidence of a strongly nonlinear relationship between wet deposition of sulfate and SO_2 emissions is limited to extensive historical data in Europe." (p 139). Specific comments on the "evidence" against nonlinearity follows:

- p 42, also p 84. "In theory, the amount of H_2O_2 formed in gas-phase reactions and taken up in cloud water and precipitation, is sufficient to oxidize a large fraction of S(IV)." Many photochemical calculations of the PBL predict a H_2O_2 concentration of a few tenths to approximately one ppb (Schiavone and Graedel, 1981; Rodhe, et al, 1981; Hov, 1983). In order to account for the composition of summertime precipitation in the northeastern U.S., several times this amount of oxidant and SO_2 is required. It is certainly possible that future calculations or experiments will show that $[H_2O_2]>[SO_2]$, perhaps as a result of an in-cloud or free tropospheric source of H_2O_2. It is misleading, however, to imply that a large enough oxidant supply has been identified.

- p 50. "The most important attachment process under most in-cloud conditions is undoubtedly nucleation." Judging from a following sentence, diffusional attachment (of gases and particles) appears to be a subset of "attachment."

Either there is a semantic difficulty or the role of gas phase SO_2 and HNO_3 in acidifying precipitation is seriously understated.

- p 80. The criticism of the nonlinearity produced in Rodhe's model is supported by many other experimental and theoretical studies (see, e.g., Miller, 1978; Hov and Isaksen, 1981). Although it appears likely that the gas phase oxidation of SO_2 is linear, there is no assurance that the aqueous phase oxidation is likewise linear. It is a deficiency of the main text (Chapters 1-5) that the relative amounts of gas and aqueous phase oxidation are not treated. Estimates of the relative importance of these processes have been made based upon the isotopic composition of precipitation (Holt, et al, 1981), the abundance of aerosol SO_4^{2-} (Newman, 1979; McNaughton and Scott, 1980), and a comparison of the acidity of precipitation and aerosol (Newman, 1979; Scott, 1982). At this point, the evidence, though largely inferential, points strongly to the in-cloud oxidation process as being the largest contributor of SO_4^{2-} to precipitation (Oppenheimer, 1983). The concern is that the aqueous pathway is the most significant and that it is nonlinear due to either pH inhibition or oxidant limitation.
- p 120-123. Comparison of Hubbard Brook data with emissions. It is misleading to base this comparison upon two years of monitoring and emissions data, namely 1965 and 1978. Emissions have a broad maximum around 1970 which is not reflected in precipitation composition. The two sets of curves, in fact, look sufficiently dissimilar such that one could argue that there is a complicated nonlinear relation between emissions and deposition.
- p 135. The NO_3^- to SO_4^{2-} ratios do not justify the conclusion that there is sufficient oxidant for all or most of the SO_2 within eastern North America. It admittedly is more straightforward to assume that equal deposition and emission ratios imply a high removal fraction for both substances than to arrive at an

explanation for why the average removal fractions are both equal but substantially less than one. The proposed high removal efficiency of NO_x is based upon the rapid formation of HNO_3 and the high solubility of HNO_3. A high NO_x wet removal efficiency is, however, not in accord with summertime, air quality observations in moderately polluted areas which indicate

$$\frac{SO_4^{2-}}{SO_2} > \frac{HNO_3 + NO_3^-}{NO_x} .$$

Perhaps HNO_3 is rapidly removed by dry deposition thereby making it unavailable for wet deposition. A NO_3^- to SO_4^{2-} molar ratio in precipitation equal to emissions could then occur without requiring efficient scavenging of S compounds.

- p 137. The data in Table 4.9 reflects the different average heights of NO_x and SO_2 emission sources. In general, during the nighttime $NO_x > SO_2$. This occurs, in part, because low level NO_x emissions are trapped above the boundary layer.

III. Source Attribution:

The text contains a good description of the monitoring evidence to the effect that receptor areas are impacted from many source regions, sometimes simultaneously. The complexity of the source attribution problem is conveyed as are the hopes and shortcomings of several diagnostic methods. The notion of strong mixing is, however, considerably overstated due to the authors' reliance on long term (monthly) average monitoring data.

Holt, B.D., Cunningham, D.T., and Kumar, R. (1981). Oxygen isotopy of atmospheric sulfates. Environ. Sci. Tech. 15, 804-808.

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Review of National Academy Report on Acid Deposition

This report focuses upon the relationships between emissions of acid precursors and the deposition of acidic substances. The stated purpose is "to assess the current state of scientific information that can be marshaled to describe those relationships in the hope that our assessment will be valuable to decision makers in the government and in the private sector" (pp. 1-2).

Overall, the report exhibits a number of positive qualities, but in my judgment it is seriously flawed. On the positive side, it delineates well the scientific issues that confront the regulatory sector. The red herring of natural sources is readily dispensed with (p. 3). The scientific issue is thus drawn as establishing the relationships between anthropogenic emissions and deposition. The report also defines the sub-issues of nonlinearity and distant vs. local sources. The report draws the conclusion that "evidence exists for long-range transport of pollutants leading to acid deposition", but cautions that "the relative contributions of specific source regions to specific receptor sites currently remain unknown" (p. 5). The report points out gaps in knowledge requisite to establishing such contributions and suggests pertinent laboratory, field, and modeling studies to better define such relationships. The report concludes that at the present level of understanding "we cannot objectively predict the consequences for deposition in ecologically sensitive areas of changing the spatial pattern of emissions in eastern North America, such as by reducing emissions in one area by a larger percentage than in other areas" (p. 11). In my judgment, the report makes an adequate case for the above conclusions. However, as I argue below, the report might well have offered some guidance, particularly with respect to the latter question.

On the negative side, I submit that the report is deficient insofar as it focuses, almost entirely, on long-term average (e.g., annual) deposition, to the exclusion of consideration of information that has been gained from shorter-term measurements. While such a focus may be appropriate from the perspective of ecological concerns and/or from a regulatory perspective, a wealth of detail is lost that is pertinent to the mechanism of acid deposition, and pertinent, therefore, to the stated subject of the report. The focus on long-term relationships between emissions and deposition leads to a number of conclusions that either are erroneous or subject to misinterpretation or, alternatively, are so narrowly drawn as to border upon the self-evident. I call particular attention to the following:

(a) "Pollutants are being thoroughly mixed over a region with linear dimensions up to 1000 km" (p. 9). This conclusion derives from the claimed near-constancy (in space and time) of the ratio of long-term average sulfate and nitrate concentrations in precipitation and the near-equality of this ratio to the ratio of the oxides in emissions. The statement is patently incorrect if we take "thoroughly mixed" in the usual sense of "exhibiting uniform concentration over the volume in question, at a given instant or over a given period of time." Evidently, the authors mean simply to say that the ratio of long-term average atmospheric concentrations is uniform spatially. In any event, the statement as it stands is erroneous and certainly detrimental to conveying the authors' point.

(b) "There is no evidence for strong nonlinearity in the relationships between long-term average emissions and deposition" (p. 7). Presumably the authors mean to say here, "There is no evidence for strong nonlinearity in the relationships between long-term average emissions and long-term average deposition." Accepting that, the statement summarizes the search for such a relationship in available, long-term records of precipitation concentration. As it turns out, there is essentially only one station that meets the authors' criteria for such records of acceptable quality, and the authors claim to discern no such relationship for that station. While that may be argued (and I am sure it will be), restricting the discussion to long-term averages excludes a wealth of evidence from short-term measurements (event or sub-event) that is demonstrative of mechanistic nonlinearities, the understanding of which is crucial to the description of the source-receptor relationship in acid deposition.

(c) "If we assume that all other factors, including meteorology, remain unchanged, the annual average concentration of sulfate in precipitation at a given site should be reduced in proportion to a reduction in SO_2 and sulfate transported to that site from a source or region of sources" (p. 10). This statement is so highly restrictive as to be essentially useless. Strictly, it deals only with the relationship between annual average concentration of sulfate in precipitation at a given "site" and, presumably, annual average atmospheric SO_2 and sulfate at that "site," under the assumption that "all other factors, including meteorology, remain unchanged." Even granting the validity of the statement as it stands, the statement is all the more important for what it does not treat, i.e., (1) the relationship between emissions and annual average atmospheric concentrations at sites remote from emissions, and (2) the factors which are assumed to remain unchanged. While it might be hard to quarrel, on the basis of annual-average measurements, with the statement as it stands (although I can think of at least three mechanistic reasons why it might not be expected to hold in the short term and can cite, as well, any number of studies to that effect), I am concerned that the statement may be misconstrued as relating deposition to emissions, particularly insofar as it appears under the heading "Implications for Emission-Control Strategies," and immediately follows the statement that "analysis of observational data provides guidance for assessing the consequences of changing SO_2 emissions for wet deposition of sulfate."

(d) "Assuming that all other emissions and conditions remain unchanged, we would expect that if the molar ratio [of SO_2 to NO_x] in emissions in eastern North America were changed by changing SO_2 emissions, a similar change would occur in the ratio of sulfate to nitrate in wet deposition" (p. 10). The authors then go on to qualify the statement, indicating that "because the analysis is based on spatial distributions, its applicability is limited to circumstances in which the spatial distribution of emissions is not changed." Here, as above, I am concerned about possible

4

miscontruction of the intent of the authors' statement. I am sure that some will see in this statement a policy implication that if sulfur oxide emissions are to be reduced, they should be reduced in such a way as to preserve the existing spatial distribution. On the other hand, I would foresee others who would take statement (a) above, that "pollutants are being thoroughly mixed over a region with linear dimension up to 1000 km," as suggesting that reduction in SO_2 emissions anywhere within the region will be equally effective in reducing annual average deposition of sulfate at all other points in the region. I submit that the proper strategy for emissions reduction to protect ecologically sensitive regions lies somewhere between these two extremes. Unfortunately, the report provides very little guidance to the policy makers who must formulate such a strategy.

In addition to the foregoing general comments, I have a number of comments relative to the linearity-nonlinearity issue. But first we must examine why linearity-nonlinearity is of interest at all. Clearly, if the geographical region is taken sufficiently large, then the long-term total deposition of SO_2 and $SO_4^=$ integrated over this area is linear in emission of SO_2 in this area, and for that matter equal. The question of nonlinearity in long-term deposition is therefore inherently a question of whether the scale of transport from source to receptor is influenced by the emission source strength. Clearly also, any negative departure from linearity in a given receptor region must be compensated by a positive departure from linearity in some other receptor region or regions. Thus, it is evident that the entire question of linearity-nonlinearity is deeply imbedded in the larger question of the scale of transport of the pollutants of concern. This point is not well brought out in the report. The failure to appreciate this point may be responsible for some of the confusion in the report over the question of nonlinearity.

Some specific comments on the treatment on nonlinearity follow.

(1) For all the care given to the definition of linearity (pp. 72-75), the report still seems to confuse linearity with proportionality. Thus, (p. 116): "The central question is whether the data [obtained from monitoring networks] can be used to judge whether deposition is linearly or nonlinearly related to emissions.... If the relationship is linear, a change in emissions would be reflected in a proportionate change in deposition; if it is nonlinear, the change in deposition, if any, would be disproportionate." The second statement above is at best loosely phrased and at worst flat out wrong. It could be corrected as follows: "If the relationship is linear, a change in emissions from a given source (or set of sources) would be reflected in a proportionate change in deposition due to that source (or set of sources)," and similarly for the second clause. The addition of the logical connection between the source and the receptor is, in my judgment, central to the entire question of acid deposition, and ultimately to the question of control strategy. However, setting that aside for the moment, it is disappointing to say the least to see propagation of such confusion in this forum.

Going beyond definitions, we see that the foregoing misconception is carried over into the discussion of the model runs by Samson (p. 76). Here, calculations are compared with and without the contribution of a "background" source. The report states that the shift from the solid to the dashed sets of curves depicted in Figures 3.1 and 3.2 is "the result of eliminating the trivial source of nonlinearity arising from the background source, term B in the equation, c = kS + B." This result is indeed trivial but it is *not a nonlinearity* and in any event is an observation that should hardly warrant discussion. The only reason that such a discussion can possibly have persisted into the final report is an inherent lack of understanding of the linearity-nonlinearity concept.

One further amusing (or saddening) point is the passing reference in the same paragraph to Figure 3.2 depicting "a result that is essentially linear (with proportionality constants less than unity)." The point of figures such as 3.1 and 3.2 is that *any departure* from the one-to-one line of percent Δ $SO_4^=$ concentration *vs.* percent Δ SO_2 (concentration or emission), sulfate concentrations from other, unchanged sources having first been subtracted out, is an inherent nonlinearity. In fact, the 24- and 48-hour graphs represent a departure from linearity of *ca.* 30%, potentially very important in the context of control strategies. This is not to argue that the model calculations are correct, but only that they are incorrectly interpreted.

(2) The report argues at some length (pp. 75-81) that model calculations of Rodhe et al. suggesting nonlinearity may be an artifact as a consequence of the incorporation in the model of a radical termination step involving SO_2, whereas the actual reaction may well be a chain propagation step: "The participation of reaction (3.1) results in a direct nonlinear feedback into the SO_2 oxidation mechanism, while reaction (3.2) does not seriously perturb the concentration of the hydroxy radical" (p. 78). This argument seems flawed by the following reasoning. We note (p. 80) that in the simulation studies of Calvert and Stockwell, only about 10% of $HO-HO_2$ radical termination occurs through the $HO-NO_2$ reaction, for the quite high NO_x concentration of 100 ppb (and less for lower NO_x; indeed, the report suggests a curious quadratic dependence). In any event, we note that the rate constant of the $OH-NO_2$ reaction is about tenfold that of the $OH-SO_2$ reaction, so that for 100 ppb SO_2, only 1% of radical termination would be due to SO_4 (again less for lower SO_2). Thus, the possibility of any significant influence on radical concentration due to SO_2 termination reactions would appear to be ruled out.

(3) The discussion of nonlinearity in SO_2 deposition due to aqueous-phase processes (cloud, rain) is short (1.5 pages; pp. 81-82) and superficial. Reference is made essentially only to the H_2O_2 oxidation mechanism of SO_2 oxidation, focusing principally on the limiting reagent process. No discussion is given at all of the pH dependence of SO_2 solubility and aqueous reaction kinetics, which would be inherently nonlinear insofar as H_2SO_4 (and to a lesser extent SO_2 itself) would influence cloudwater pH. This process has been the subject of much research over the past decade (as summarized in Appendix A, pp. 178-193), but little of this research finds it way into the discussion in the text. Other types of processes leading to

nonlinearity (e.g., non-constant nucleation efficiency as a function of aerosol loading) are also not treated.

In summary, the relationship of the linearity-nonlinearity issue to the larger problem of scale of transport and control strategies does not appear to be adequately recognized. Moreover, the details of the discussion of nonlinearity are superficial and flawed, and little recognition is given of the importance of the fact that nonlinearities, as exhibited in short-term phenomena, can influence the source receptor relationship. For these reasons, little import should be given to the conclusion of a lack of evidence for nonlinearity in the relationship between long-term average emissions and deposition.

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August 29, 1983

Dr. Bernard Manowitz
Chairman, Department of
Applied Sciences
Brookhaven National Laboratory
Upton, New York 11973

Dear Dr. Manowitz:

I am writing to you in your capacity as Chairman of the National Laboratory Consortium of the Interagency Task Force on Acid Precipitation. In response to your request we have reviewed the National Academy of Sciences' report entitled "Acid Deposition: Atmospheric Processes in Eastern North America".

The attached comments were provided by a review team comprised of research scientists from several divisions within the Laboratory and from a local institution we collaborate with in several research activities. This team of scientists collectively presents considerable experience in the field of atmospheric deposition. The reviewers consisted of (A) S. E. Lindberg, a chemist with 7 years' experience and over 40 publications in the area of air pollution research with special emphasis on forest canopy/atmosphere interactions and G. M. Lovett, a biologist with 5 years' experience and 7 publications in the area of atmospheric deposition to plant canopies and chemical interactions between plants and the atmosphere; (B) F. C. Kornegay, a meteorologist with 8 years of experience and over 20 publications in the area of air quality impacts of energy production and utilization, with special emphasis on atmospheric turbulence and diffusion, and (C) B. B. Hicks, a meteorologist with over 20 years of experience and 70 publications in the areas of precipitation scavenging, dry deposition, and atmosphere/surface exchange phenomena. We believe these people are highly qualified to review the National Academy of Sciences' report.

Our reviewers express concern about inadequate discussion of uncertainty levels associated with the assumptions upon which conclusions of the NAS report are based. We believe this is an important point because of the natural tendency of nontechnical readers to develop a position or make a decision without regard to the uncertainty associated with the conclusions of a given study. You will also note an objection to the chemical, rather than a meteorological, focus of the nonlinearity issue.

Please let me know if you need additional information.

Sincerely,

Chester R. Richmond

Chester R. Richmond
Associate Director for Biomedical
and Environmental Sciences

CRR:ja

Attachments

cc: S. I. Auerbach
B. B. Hicks
F. C. Kornegay
S. E. Lindberg
G. K. Lovett

Review ORNL-A

The NAS Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation was given the difficult task of addressing an exceedingly complex issue in an objective scientific manner. We feel that the committee has presented a reasonable "best guess" regarding the linearity between emissions and deposition. The challenge now is for the scientific community to refute, substantiate, or provide reason to alter this conclusion. For this reason, the conclusions in this document should not be used for establishing ultimate air quality regulations, but can be very useful in the initial development of policy.

The following points are made in support of this contention and discussed further below: (1) uncertainty is not clearly expressed; (2) conflicting European data is summarily dismissed; and (3) many potential problems with the Hubbard Brook data are not considered in detail.

1. Uncertainty - The degree of uncertainty in many of the calculations and assumptions used to conclude that there is not a strong case for nonlinearity is buried throughout the chapters and appendices. In some cases, uncertainty has been quantified, while in others it has not. When the reader considers all of the sources of uncertainty involved, he is left with the unmistakable conclusion that the 1:1 relationship between emissions and deposition attributed to the report by the press is highly uncertain.

2. European data - Not enough time has been spent in analysis of the European network data which provides evidence for nonlinearity. The European data is far more extensive in both space and time than the single Hubbard Brook data set on which so much emphasis has been placed. The reasons for dismissing these data may also apply to the Hubbard Brook data as well (see below). The Hubbard Brook data set is only one of four wet deposition data sets cited in the report. The others were dismissed because of "too much scatter," "uncertain quality control," and because they are "difficult to interpret." Perhaps all of these data warrant further analysis.

3. Hubbard Brook data set - The analysis of the Hubbard Brook data, on which the important conclusion on linearity is primarily based, leaves some questions in the minds of the reader. The contradictory European data on sulfur deposition are dismissed as being "somewhat uncertain" because of changes in analytical and sampling techniques during the period of observation. No attempt is made to convince the reader that the Hubbard Brook data are not subject to the same uncertainties. Did the site operators and analytical techniques for Hubbard Brook change between 1964 and 1978? For instance, ion chromotography has supplanted automated colorimetry as the technique of choice for analysis of sulfate and nitrate in water samples--did such a change occur at the laboratory analyzing Hubbard Brook samples?

   Another point involves the use of annual average trends in NO_3^-, SO_4^{2-}, and the SO_4^{2-}/NO_3^- ratio in precipitation. Galloway and Likens (Atmospheric Environment 15:1081-1085, 1981) reported that the trends in deposition at Hubbard Brook were seasonal, with NO_3^- increasing in the summer and SO_4^{2-} decreasing in the winter. Thus, the SO_4^{2-}/NO_3^- ratio decreased year-round, but for different reasons in different seasons. It seems necessary to show that the seasonal patterns of deposition match the seasonal patterns of emissions, rather than analyzing the composited annual data as done in Chapter 4.

The fact that the Hubbard Brook data is bulk precipitation clouds the entire analysis. Keeping in mind that this is the only type of long-term data available, one needs to consider its limitations. Bulk samples contain an unknown, but generally small contribution of dry deposition, particularly at sites distant from local sources and particularly for gases. Yet, the Hubbard Brook researchers have estimated that dry deposition of SO_2 can be a significant source of deposited S, which is not collected in bulk samples. Recent data on the possible importance of dry deposited HNO_3 vapor add further evidence to support the statement in the report that dry deposition may be comparable to wet. The fact that the case for linearity has been based on samples containing primarily wet deposited material further emphasizes the uncertainty of the conclusions.

Review ORNL-B

SUBJECT: Acid Deposition Document Review

I felt that the document was a farily complete review of pre-1982 acid rain research. The material covered was extensive, but I certainly noticed bias in the writing towards conventional modeling studies. Little mention of other studies, such as ANL's work on examining the potential formation mechanism of sulfates in precipitation, was made. My major criticism of the document, however, is that modeling is in fact denounced as a regulatory tool in the summary (p. 5), but when one muddles through the text, the bottom line on p. 83 reads ".. we advise caution in projecting changes in deposition patterns that result from changes in emissions of precursor gases." I feel that such a summarizing statement in the modeling chapter is a de facto endorsement of the continued reliance on LRT models, an endorsement that has no basis in scientific fact.

Specific Comments

Page	Comment
7	The conclusion of no evidence of non-linearity is not borne out by the data. More recent work, particularly by McLaughlin, indicates the importance of local sources.
11	I strongly support the need for less modeling and more direct field work. However, no acknowledgement of past long distance field work was given, and no recommendations as to best techniques were made.
59	If the gross statistical codes are as good as the transport codes, this is overwhelming evidence that the transport codes are missing the basic physics.
67	The reference to Fig. 2.5 indicates uncertainty to the author. To me, it indicates a total inability to determine where material goes, which implies an inability to provide any useful insight into the problem.
83	I find the conclusion of advising caution to be far too weak. As I read the chapter, and the data that are referenced, my conclusion would be that present LRT models are of no value in a regulatory process, and should not be used in any way, shape, or form.
111	I've never seen so many "ifs" and "thens" in a paragraph in my short life as in the first paragraph. Also, the reliance on such a tenuous assumption, when other studies have been unable to correlate SO_2 and SO_4 concentrations, is not in keeping with a national summary.
119	If no changes in long-term precipitation pH in the only decent record can be detected, and if no change in H^+ deposition can be noted, where is the problem?

For my summary, I would repeat that I, perhaps being overly sensitive, detect an unpalatable bias in the document. I also feel that the report is mostly complete, but serves only as a chronicle of work done to 1982, without shedding much light on what to do next.

Review ORNL-C -

I regret that I have not had time to review the NAS Acid Deposition Document as thoroughly as I would have liked, nor am I going to have time during the next six weeks. However there are a couple of points that seem obvious and which should be emphasized.

1. The report is an excellent document. It presents results that are well thought out and which are appropriately qualified.

2. Some of the strong statements attributed to the document by the press are not found in the report. In particular, I have heard reports that the document suggests that dry deposition can be neglected in comparison to wet. This is not stated in the document although it does appear to be the personal opinion of at least one of the authors and was stated at a press conference concerning the document. In reality, of course, dry deposition is a nearer-source phenomenon than wet. If we are solely concerned about tall-stack emissions from power plants, then clearly wet deposition will dominate. However, if we are worried about natural emissions, automotive exhausts, or other surface sources, dry will dominate wet. The corollaries are important.

   (a) People who study what comes down in rain will find a major role of tall-stack emissions, because precipitation is where such emissions are focused.

   (b) Other workers who study concentrations in air near the surface or dry deposition of particles will find a major influence of more local sources, for the same reason.

   (c) Those who addrdss the problem from the point of view of sulfur only, and power-plant stack controls to reduce sulfur emissions, will find little need to worry greatly about dry deposition far from sources, other than to provide background data for purposes of comparison.

3. The question of chemical nonlinearities is handled nicely, but I hope there are more qualifying statments than I detected on my perusal.

   (a) The extremes corresponding to strong nonlinearity and negligible nonlinearity can be handled in the models that presently exist. A simple sensitivity test would have been very worthwhile.

   (b) The question of chemical nonlinearity has been around for a long time, and has received a lot of thought. A major contribution to net effective nonlinearity (i.e. between stack emissions and deposition to ecosystems) may indeed be chemical, but we must also worry about meteorological nonlinearity. That is, the tendency for air from the southwest to be far more humid and thundery, hence more like an efficient chemical reactor than drier air masses associated with other wind vectors. In essence, I guess I object to the chemical focus of the non-linearity issue. I feel that it is more a meteorological matter, and I think it has been blown out of proportion as an issue.

4. The utility of models is discussed, but not in as sanguine a fashion as some reports have indicated. Again, several points are obvious.

   (a) No organized model can hope to reproduce the randomness of nature. Thus no model can hope to relate (except in average terms) the experience at any single receptor to any specific, distance source. The focus on very detailed, deterministic models is not to provide a definitive tool for proving source/receptor relations, but rather to study the factors which combine to cause events. A description of the average can be developed by running such models often, but this is like using a statistical mechanics model of molecular kinetic energy to determine the temperature of a fluid by integrating the energies of molecules, calculated individually. We have a better tool available -- a thermometer.

   (b) The use of statistical models is appropriate. In fact, we understand a lot about long-distance dispersion, on the average, and about its statistics. This knowledge can be applied with confidence, but only to the case of long averaging times and to relatively large areas.

   (c) Attempts to consider single-sources and single receptors are certainly poorly founded. Such questions are posed not by statisticians or meteorologists, who know better, but by politicians and industry representatives. The matter is somewhat like wanting to base a statistical average on a sample of one.

The report does not seem to contain any outrageous statements about the use (and abuse) of models, but again such statements have been credited to it. I fear that the cause might again be the press conference, or contact with some individual panel members. Certainly there is a need to recognize the specific utility of different kinds of models, Eulerian, Langrangian, Statistical, and Statistical Trajectory, and to recognize that the entire field of modeling cannot be criticized because of the failure of one kind of model to answer questions best suited to another.

To a considerable extent, this is where the US/Canada exercise fell down. The work was based on a random selection of appropriate and inappropriate models, whose results were then combined without apparent sensitivity to the fact that there was a problem.

I hope that these hip-shooting comments are of use. From my personal point of view, I can only regret that I did not have the opportunity to see the proofs of the material attributed to me in the report. It is said far better in the EPA/CARP document, it has a lot of typos, and some of the editing seems to have changed the tone in some places.

Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509) 376-8639
Telex 15-2874

August 23, 1983

Dr. Bernard Manowitz
Chairman, Dept. of Applied Sciences
Brookhaven National Laboratory
Upton, NY 11973

Dear Bernie:

In your capacity as Chairman of the National Laboratory Consortium for Acid Deposition, you requested that we, as a NLC member Laboratory, review the National Academy of Sciences report, "Acid Deposition Atmospheric Processes in Eastern North America." Three PNL scientists, W.G.N. Slinn, M.T. Dana, and R.C. Easter, have carefully and thoroughly reviewed the report. The three were selected because of their longstanding involvement in research on precipitation scavenging processes, cloud physics and chemistry, and more specifically in recent years, the "acid rain" problem.

The findings of the three scientists regarding deficiencies of the report were uniform and unanimous. The attached summary comments represent their consolidated view.

The focus of their review was to identify the report's inadequacies and to document the unsatisfactory treatment of the nonlinearity issue. It should also be stated that the report's discussion of future research needs was good and that our scientists concur in the needs identified and the emphasis given.

Very truly yours,

C. E. Elderkin

C. E. Elderkin,
Associate Department Manager
Geosciences Research and
  Engineering Department

cc: D. E. Olesen, PNL Laboratory Director
    W. R. Wiley, PNL Director of Research
    W. J. Bair, PNL Program Manager

PNL REVIEW OF NATIONAL ACADEMY OF SCIENCES REPORT "ACID DEPOSITION ATMOSPHERIC PROCESSE IN EASTERN NORTH AMÊRICA"

The objectives of the NAS study project are stated in terms of answering the questions (p. 24): "If this goal [reducing H^+ deposition by 50%] were adopted, by how much would emissions have to be reduced? Conversely, by how much would deposition rates be reduced if there were specific reductions in emission rates?" The committee (p. 139): "...concludes that there is no evidence for a strong nonlinearity in the relationships between average emissions and depositions in eastern North America." In this context, linearity means proportionality of deposition to emissions. Although considerable qualifications are applied to this conclusion, we believe that the limited available evidence, as generally well covered by the report, does not support such a conclusion, or, that an opposite conclusion (nonlinearity) could be equally supported.

We will concentrate this review on the two major observations which the NAS study uses to support the above conclusion: 1) the apparent spatial uniformity of the sulfate/nitrate (S/N) ratios in eastern North America, and 2) the similarity in time trends between sulfur and nitrate emissions and the Hubbard Brook deposition data. In addition, we will comment on the report's treatment of chemical reaction mechanisms.

Sulfate/Nitrate Ratios

The committee found that the ratio of sulfate to nitrate in deposition was "nearly constant" at many locations in eastern North America and similar to state-by-state emission ratios. In Europe, a latitude (or distance from major source regions) dependence was found (Fig. 4.16 and Table 4.7), the ratio increasing with distance. The committee claims no such dependence for North America, but in fact if one constructs a table like Table 4.7 for North America, a similar trend can be identified. The ratio contour on Figure 4.17 for 1.2 at about 2 degrees latitude from the midwestern source region (where the ratio is 1) and the 1.6 contour at about 5 degrees compare favorably with the European results. The European data extend much farther (over about 15 degrees latitude), and the committee seems to have not noticed this.

The report's argument seems to be that: NO_x is readily converted to nitric acid which is scavenged efficiently, S/N ratios in deposition are equivalent to those in emissions; thus, SO_2 must be efficiently scavenged, implying nearly complete aqueous phase oxidation (no oxidant deficit). This logic is based on annual and regional averages (Figs. 4.17, 4.18 and Golomb's analysis, referred to on page 134-135), but considerable variations occur on shorter time scales. The MAP3S/PCN data of table 4.8 show a S/N ratio of 1.4± .1 for the warm months and .86± .19 for the cool months. Our own analysis of an expanded data set (MAP3S, 1981; MAP3S, 1983) for four inland northeast U.S. sites shows an even greater seasonal variation if one compares summer (Jun-Aug) to winter (Dec-Feb): 1.6± .1, and .53± .21, respectively. Inadequate discussion of the seasonal variation is presented in the report, especially in light of the at least implied lack of oxidant deficit.

Explanation of the apparent spatial uniformity of the ratio "...requires considerable specualtion." There is little hard evidence (as is admitted) to relate this uniformity (if true) to the linearity question. Furthermore, resemblance of the emissions to depositions (Figs. 4.17 and 4.18) may be purely fortuitous. Going to finer detail than annual or region averages, one finds (Table 4.9) significant contraindications of linearity. The concluded efficient scavenging of SO_2 also seems to be contradicted by the data of Figure 4.1 which shows a large area of quite high SO_2 air concentration. The question of whether or not there is adequate oxidant (e.g., H_2O_2) to consume this SO_2 is not fully discussed in the report.

In summary, on the basis of the included evidence and argument, the conclusion of an absence of nonlinearity does not seem any more justified than a conclusion to the contrary. The potential popularization of the committee's conclusion would thus be detrimental to a proper scientific (and regulatory) resolution of the acidic deposition question.

Hubbard Brook Data

It is unfortunate that the committee was forced to place so much weight on the data from a single deposition monitoring site. We agree that the Hubbard Brook data are the best of more than 5 years duration, but the site is located outside the region of highest recent acidic deposition (Figs. 4.3 and 4.4), and a single site's data--however high in quality--cannot serve to characterize a region, particularly if the measurements involve strong dependence on meteorological variations. The time trend regressions (on p. 119, p. 133, and Figure 4.19) require much more discussion of the statistical significance and validity. In particular, the tests of the assumptions regarding independence and normality (p. 119) need to be more fully detailed. Extreme caution should be exercised in evaluating apparent trends in light of several important variabilities (MAP3S, 1982):

- source configuration and fluctuation
- atmospheric behavior (storm dynamics, precipitation features)
- changes in sampling practice and land use.

Long averaging times, e.g., years, will tend to smooth some of these variations, but long-term climatological trends may influence the record--even over 15 or 18 years. Any viable conclusions regarding cause-effect relationships and predictions of future behavior are particularly difficult to draw with confidence, especially when considering an isolated data set. Failure of the report to adequately treat the potential variables or provide a detailed statistical case weakens the significance of the conclusions regarding the Hubbard Brook data. In particular, the "similarity" of the emission and deposition trends in Figure 4.19 is not sufficiently quantified.

Chemical Processes

The discussion of chemical processes in Section 3 (p. 75-82) overemphasizes gas phase reaction mechanisms relative to the aqueous phase, in conflict with the well balanced approach in Appendix A. In particular, a detailed argument is made to show that the model of Rodhe, et al. may be improved with the result of deemphasizing nonlinear effects of the gas phase reaction process (p. 75-81). Thence, only brief mention of the potential non-linear effects of aqueous phase mechanisms (e.g., through limitation of oxidant) is given (p. 81-82). It is admitted that "Existing analytical data for H_2O_2 in clouds do not allow an unambiguous conclusion to be reached today on the possible importance of these nonlinear effects." However, somewhat of a case for linearity of aqueous phase processes is made in the conclusions to the section: "measurements of oxidant concentration in cloud water, although limited, suggest that concentrations may be sufficient in eastern North America for complete oxidation of SO_2..." The relative importance of gas versus aqueous-phase mechanisms is not sufficiently treated, and the conclusion regarding the linearity of the latter is ambiguous. Therefore, there is no firm support for the linearity argument from the study of chemical processes.

References

MAP3S (1980). The MAP3S Precipitation Chemistry Network: Fourth Periodic Summary Report, (1980), PNL-4144, Battelle, Pacific Northwest Laboratory, Richland, WA. Dec. 1981.

MAP3S (1983). The MAP3S Precipitation Chemistry Network: Fifth Periodic Summary Report, (1981), PNL-4599, Battelle, Pacific Northwest Laboratory, Richland, WA Feb. 1983.

MAP3S (1982). "The MAP3S Precipitation Chemistry Network: Statistical Overview for the Period 1976-1980." Atmos. Environ. 16(7): 1603-1631, 1982.

Appendix B
Reviewer BNL-A
F. Lipfert

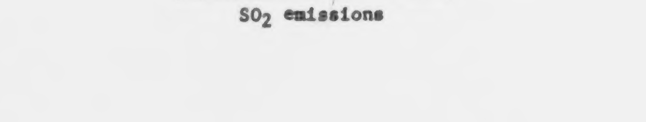
ADDENDUM TO CRITIQUE OF NAS -- CHAPTER 4

Since our original analysis in August, we have continued analyzing the Hubbard Brook precipitation chemistry data, with particular emphasis on using the electroneutrality relationship (cation-anion balance) to define particular subsets of the total data set (n = 507) of weekly samples for regression analysis. In all cases each subset contained a majority of the original data.

We find that our conclusions regarding the 1:1 relationship between ammonium in precipitation and SO_2 emissions and between nitrate in precipitation and NO_x emissions are robust; i.e., they pertain over all subsets. However, this is not the case with regard to the relationship between sulfate in precipitation and SO_2 emissions; statistical significance is achieved only in selected situations. However, in no case was the relationship, even if statistically significant, shown to be proportional; i.e., the elasticities were less than one, usually around 0.3-0.4. This means that, on a plot of $SO_4^=$ ion concentration vs SO_2 emissions, there is a substantial y-intercept (see figure below).

This finding could be interpreted in several possible ways:

- there are important emission contributions from other regions. (No evidence for this hypothesis was found in the limited analyses performed, which included emissions from the entire U.S. and from Eastern Canada).
- the basic relationship is non-linear, and the elasticity of about 0.4 represents the local slope of the curve in the region explored.
- The analyses may not be capable of detecting a proportional relationship because of either mis-specification (omitted variables) or because of errors in the variables used.



One way of selecting among these alternatives would be to repeat our time-series correlation analysis for other data sets, such as the USGS 18-year data set for New York State.

With respect to the NAS report and the ensuing debate, we stand by our original contention that the analysis presented in Chapter 4 in no way establishes linearity or proportionality between emissions and deposition. (See attached statistical review by Professor Tian.) Without appearing to prolong this rather tedious debate, some additional points of clarification should be made in response to the NCAR material submitted to the House Subcommittee on Natural Resources, Agriculture, Research and Environment on 21 September:

- The distinction between proportionality (1:1 relationship or elasticity of 1.0) and linearity is important, and is not clearly made in the NCAR materials. "Deposition tracking emissions" does not establish proportionality, only a relationship between the two.

- The temperature variable used in our analysis is not crucial to the findings. Dropping this variable from the analysis did not alter our conclusions. The intent was to represent regional climatic changes from year-to-year beyond the seasonal variation represented by our periodic function.

- Our use of a periodic seasonal adjustment variable and a precipitation variable resulted in a dramatic reduction in variance in sulfate, about 50%. Thus it cannot be argued that these are inappropriate adjustments.

- Our analysis does not use any sort of "local winds" in any way whatsoever. We assume that meteorological variations resulting in differing origins of air masses arriving at Hubbard Brook will be represented by our seasonal periodic function and the regional climatic temperature variable.

- The arguments that the apparent disproportional relationship between sulfate in precipitation at Hubbard Brook and SO_2 emissions results from differing "dominance" of certain emitting regions in differing years certainly cannot be disproven; neither can it be proven or even tested statistically. With sufficient degrees of freedom, the statistical analysis becomes singular and no confidence limits are possible. However, the fact that physically plausible relationships were indeed found for NH_4^+ (presumed to come largely from sulfate aerosol) and for NO_3^- is a strong indication that our methodology is appropriate. The lack of proportionality that we found for $SO_4^=$ cannot be ascribed to either the emissions data used or to statistical procedures alone.

Appendix C
C. Tian

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: October 27, 1983

TO: B. Manowitz

FROM: R. F. Peierls
Chairman, Dept. of Applied Mathematics

SUBJECT: Evaluation of Statistical Analyses

The enclosed evaluation of the National Academy reports conclusions on the relation between emissions and wet deposition was carried out at my request by Dr. Chengjun Tian, currently a visiting scholar in the Department of Statistics at Columbia University, and a consultant to this Department. Dr. Tian has particular expertise in the field of time series analysis, as well as general statistics. In reaching his conclusions, Dr. Tian discussed the issues extensively with other staff members here.

RFP:mck
Enclosure

cc: C. S. Kao, AO
F. Lipfert, AS

Comments On The Academy Analysis

Chengjun Tian

Based on the discussion entitled "Analysis of Historical Trends" on pages 115-126 of the NAS report, some comments are provided herewith.

It is understood that the goal was to "analyze the relationships between emissions and wet deposition using data obtained from monitoring networks", and that "the central question is whether the data can be used to judge whether deposition is linearly or nonlinearly related to emissions".

The conclusion that the data "show no indication of a significant nonlinearity" is not substantiated. The authors make this claim on the basis of plotting and simple linear-regression analysis on the Hubbard Brook data for special periods using time as the only independent factor. The statistical analysis given in the report would not lead to the stated conclusion from these data.

In view of Figure 4.14 and Figure 4.15, the annual emission of SO_2 and the annual concentration of SO'_4 from 1965 to 1978 actually do not show any linear relation between the two quantities. The zig-zag pattern of the annual concentration of SO'_4 seems to actually support the European findings of nonlinearity. This certainly shows that the relationships between emission and wet deposition are influenced by many factors. This is consistent with the comments that "year to year changes superimposed on the long-term trend may be related to climatological influences", (p. 119), "relationships influenced by long-range transport to rural areas" and "several stations reveal more complex trends throughout the period" (p. 126).

Although it is true that "both the USGS and New York State data are therefore of limited usefulness for assessing relationships between emissions and deposition influenced by long-range transport to rural areas" (p. 126), it appears that both data could be very useful in checking the findings obtained from Hubbard Brook data.

The analysis appears to indicate that the relationship contains both static and dynamic parts. This means that one needs to apply both typical multiple regression analysis and time series analysis (especially intervention analysis and seasonal adjustment) to correctly formulate the relationship. The simple, intuitive and even rough analysis used in the report is not adequate to ensure a correct conclusion.

10/27/83

Appendix D
Reviewer PNL
W.G.N. Slinn

Dr. Bernard Manowitz
Chairman, Dept. of Applied Science
Brookhaven National Laboratory
Upton, Long Island, NY 11973

Dear Bernie:

At your request, in your capacity as Chairman of the National Laboratory Consortium involved in acidic deposition research, this letter is provided as background material to assist you with your forthcoming testimony to the Senate Committee on Public Works. The letter deals with three main points: (1) some comments about the ratios of sulfate to nitrate concentrations in precipitation in the Northeastern U.S.; (2) comments about the hypothesis contained in the National Academy of Science's report on Acid Deposition; and (3) comments about the NAS predictions derived from their hypothesis.

1. Concerning the ratios of sulfate to nitrate concentrations in precipitation, substantial significance was placed in the NAS report to the difference between the European and North American data. Thus, the NAS report suggested that the change in this ratio gave evidence for strong nonlinearity in the acidic deposition phenomenon in Europe. The NAS report suggested, in contrast, that the ratio did not vary significantly in the Northeastern U.S., and therefore suggested that the acidic deposition phenomenon, here, was essentially linear. However, as was stated in the earlier PNL review of the NAS report, PNL scientists did not find the NAS argument to be compelling, in part because the examined case for the Northeastern U.S. was over a shorter distance than for the European case, and in part because the NAS report did not give adequate attention to the substantial difference in the ratios for summer vs. winter precipitation.

Here, the additional point might usefully be made that the ratio can be seen, from the data in the NAS report, to change by essentially the same amount (when appropriate account is taken for both positive and negative excursions of the ratio from the appropriate mean value) regardless of the choice of origin in the Northeastern U.S. Moreover, for distance comparable to those for the European case, the ratio changes by an amount that, given the crudeness of the data and the analysis, is similar for either Europe or the Northeastern U.S. Therefore, it continues to seem clear that the ratio data for the Northeastern U.S. do not provide compelling support for the NAS hypothesis that, in the Northeastern U.S., the acidic deposition phenomena is essentially linear. In summary, as stated in the PNL review: "The conclusion of an absence of nonlinearlity <in the Northeastern U.S.> does not seem any more justified than a conclusion to the contrary."

2. The second point is a more general comment about the NAS hypothesis. To emphasize this point, the liberty is taken to review the familiar stages of the scientific method:

- Observations of some manifestations of an investigated process,
- Analysis of these observations, leading to
- Advancement of an hypothesis to explain the observations,
- Formulation of predictions based on the hypothesis,
- Design and execution of experiments to test these predictions,
- Observations and analysis of the outcome of these experiments, thereby testing the hypothesis and possibly leading to new hypotheses, and
- Continuing as necesary, until finally (limited) understanding is reached, confirmed by agreement (to within specified accuracy) between predictions and experimental results.

The above description of the well-known scientific method has been belabored, in the hope that, thereby, the following point would be clear.

It is noted, first, that the NAS report was published with the subtitle "A Review of Current Scientific Understanding." Thereby, by reference to the list (shown above) of steps in the scientific method, the NAS report should not have contained any untested hypothesis; i.e., the NAS report should have been restricted to describing topics that have passed through the full scientific cycle: observations, hypothesis, predictions, and experimental tests, finally leading to (limited) understanding. In contrast, however, a major component of the NAS report is the presentation of an untested hypothesis, dealing with the linearity/nonlinearity issue. In other words, the perceived strength of weakness of the NAS hypothesis (e.g., see the first point described in this letter) is rather of secondary importance: of prime importance is that the NAS hypothesis is an hypothesis and therefore, is not legitimately contained within a text identified to be "A Review of Current Understanding." In contrast, if the NAS report had been entitled, say, "A Review of Current Scientific Hypotheses," then probably the report would not have been subjected to such severe criticism by so many scientists.

3. And the final point to be made here concerns the prediction that the NAS Committee has made, based on the hypothesis that acidic deposition in the Northeastern U.S. is related linearly to emissions of sulfur and nitrogen compounds. In essence, the situation is this. The NAS Committee has formulated an interesting hypothesis dealing with the issue of linearity/nonlinearity of acidic deposition. Following from this hypothesis, the NAS report contains the predictions of the consequences of a particular emissions-control strategy, namely, a predicted decrease in acidic deposition in the Northeastern U.S. proportional to any reduction in emissions. Now, as can be seen in the list (shown above) describing the normal scientific method, the next step is to design and execute experiments to test the

predictions of this hypothesis. Several such experiments are listed in the NAS report, and PNL scientists have indicated substantial agreement with these research recommendations. Other experiments, to test the linearity/nonlinearity as well as other hypotheses, are being considered by the Interagency Task Force on Acid Rain, as well as by other organizations, and there seems to be little doubt that important results from such studies will soon be available.

I hope that these comments are of some value to you in your attempt to help the Nation reach a difficult decision.

Sincerely,

Dr. W.G.N. Slinn, Leader
Atmospheric Chemistry Group
Geosciences Research and
Engineering Department

cc: C.E. Elderkin, PNL

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

(516) 282-
FTS 666- 3037

Department of Applied Science

1983 NOV 21 PM 12:47

November 18, 1983

The Honorable Max Baucus
United States Senate
Washington, DC 20510

Dear Senator Baucus:

Your letter of November 3, 1983 asked me to respond to the questions, "Would the arguments of the National Laboratory scientists lead to a better control strategy or would they lead to essentially the same solution as the arguments of the National Academy group? How would they make a difference?"

The National Laboratory position is that the quantitative relationship between emissions and deposition in North America is highly uncertain; that the National Academy hypothesis of a 1:1 proportional relationship between emission and deposition when averaged over a period of a year and with dimensions in the order of a million square kilometers is unproven; and that the National Academy report as written invites the reader to interpret the established limited understanding and data too broadly.

The National Laboratory scientists do not claim that they have a better interpretation of existing data. They simply state that the existing data do not sufficiently support the National Academy hypothesis. Therefore, any control strategy defined at this time, based on this hypothesis, would not be firmly supported by scientific understanding.

The National Laboratory scientists concur with the National Academy recommendations of research needs. Quoting from p. 11 of the National Academy document:

"We believe that extensive laboratory, field, and modeling studies should be continued if we are to establish the physical and chemical mechanisms governing acid deposition. It appears to us, however, that useful information about the delivery of acids to ecologically sensitive areas by transport and transformation processes can be determined more quickly by direct empirical observation in the field than by other means. Although the results of such field studies may not yield complete detailed descriptions of the interactions of all the processes involved, the studies are likely to provide basic phenomenological evidence with sufficient reliability to form a basis for improving with near-term strategy for dealing with the problem of acid deposition in eastern North America. Indeed, the data are essential to enhance theoretical understanding and to develop improved deposition models. In the long term, however, the ultimate strategy for dealing with acid deposition will depend on the application of realistic, validated models."

A program of this type will increase our confidence that a particular control strategy will be successful. The results of such a program might lead to the same or to substantially different control strategies, but we cannot tell in advance. As an example, if substantial nonlinearities exist on a regional scale and can be quantified, such a result might lead to the opportunity for a more efficient local inter-regional control rather than the uniform intra-regional rollback strategy suggested by the Academy position.

We recognize, however, that it is sometimes necessary for legislative bodies to act on some hypotheses even when it is not firmly supported by scientific evidence.

In this case, I believe the nation would be best served by using the approach of the OSTP (Nierenberg) Committee, i.e., provide for a reduction in sulfur emissions that is least disruptive and most cost effective acknowledging the uncertainty in where and when deposition changes will occur. Should such legislation be enacted, I would hope that the legislation provide for a mid-term correction so that the results of the research programs now being undertaken can be factored effectively into modified legislation.

Sincerely,

Bernard Manowitz
Chairman

BM:mh

cc: Members of the Senate Committee
on Environment & Public Works

Testimony to the Senate Committee on Environment and Public Works on the validity and conclusions of the National Research Council report on the atmospheric processes of acid deposition in eastern North America

by

Dr. Jack D. Shannon
Environmental Research Division
Argonne National Laboratory
Argonne, IL 60439

2 November 1983

I am a meteorologist by training, and my area of research specialization is numerical modeling of long-range transport and deposition of air pollutants, primarily those related to acid deposition. I have been asked to provide my opinion on the validity and conclusions of the NRC report on the atmospheric processes of acid deposition in eastern North America.

In general, I have far more agreement than disagreement with the NRC committee. The NRC report discusses in useful detail the major atmospheric processes and our current knowledge about the processes. Nevertheless, I question the conclusiveness of some of the analyses, and hold a significantly different opinion as to the usefulness of current models of transport and deposition.

Much of the scientific discussion in the report is based upon trend analyses of emissions by EPA Regions and deposition measurements made at a single location, Hubbard Brook in New Hampshire. Compilation of emission inventories is an inexact process. As an example, three detailed estimates of sulfur dioxide emissions meant to apply to conditions in 1978, the Sulfur Regional Experiment inventory funded by the Electric Power Research Institute, the Multistate Atmospheric Power Production Pollution Study inventory funded by DOE and EPA, and the inventory produced by the working groups of the United States/Canada research effort related to the Memorandum of Intent (MOI) on Transboundary Air Pollution, differed by more than 30%, with some estimates for individual states differing by almost 100%. It is likely that historical emission estimates contain even larger uncertainties, but that does not appear to be taken into account in the report. It is my opinion that the uncertainty about the estimates for particular years in the time series of emissions is greater than the indicated change of emissions over the approximately 15 years of trend analysis. In addition, Canadian emission trends were not included, even though modeling studies and air mass trajectory analyses indicate that the contribution to total sulfur deposition at Hubbard Brook from Canadian sources should be about 25%. (Inclusion of Canadian emission data might well have strengthened rather than weakened the argument of the NRC committee.)

The Hubbard Brook measurements examined statistically were weekly samples of bulk deposition. Bulk deposition consists of wet deposition plus some ill-defined portion of dry deposition. As a rule, bulk sampling is subject to more contamination, such as from local resuspension of large soil particles, than is wet-only sampling. No confidence limits as to the representativeness and accuracy of the Hubbard Brook data are provided. The trend analysis considers emissions totaled by EPA Regions at five-year intervals. The annual emissions within the five-year intervals, and state trends within EPA Regions may have been significantly different. The gradual introduction of tall stacks and associated increase in long-range transport (per unit emission) is not considered. The committee faced a difficult problem in trying to perform historical trend analysis with extremely limited data. Their conclusions as to the absence of "strong" nonlinearities may well be accurate, but can hardly be said to be definitive as to questions of linearity.

The inconsistency between apparent nonlinearity in European emission/deposition trends and "no strong nonlinearity" in North American emission/deposition trends is not resolved in the NRC report. Obviously the NRC committee was constrained in time and resources, and chose to restrict their analysis to North American data. The possible causes of the apparent European nonlinearity listed in the report—differences in meteorology, latitude, or spatial distribution of sources — are only mentioned, not evaluated. There is a modeling exercise underway to evaluate European models on North American data, and North American models on European data, but the effort is still in initial stages, and the models may all be linear in their emission/deposition parameterizations.

The NRC report takes a very dim view of the capabilities of current or state-of-the-art models of long-range transport and deposition. Unfortunately, the NRC committee contained no members whose primary expertise was in modeling long-range transport and deposition of acidifying pollutants. Their conclusions seem to be based primarily on limited model comparisons with data performed as part of the MOI research efforts. As one who took part in the MOI model intercomparisons, I am aware of serious limitations in the study. First, as mentioned previously, there was considerable uncertainty in the emission inventory. Second, almost all of the wet deposition measurements considered were monthly samples in southeastern Canada in the CANSAP network, and contained large uncertainties in both precipitation chemistry and precipitation quantity. Third, the values were point measurements, while all of the models sought to simulate deposition representative of a region of perhaps 100 kilometers in on side. Fourth, the comparison was primarily for two months, January and July 1978, while most of the models were developed to simulate seasonal or annual deposition. I have since compared simulations of annual wet deposition by my model, the ASTRAP model, with observations of 1980 annual wet deposition of sulfate and of nitrate in four major U.S. and Canadian precipitation chemistry networks, and found correlations between predictions and observations of about 0.85, or explanation of about 70 to 75% of the variance in the observations. Much of the remaining variance may be due to uncertainties in emissions or measurements. This result was not available to the NRC committee when they produced their report, as it is part of an ongoing model evaluation and is not yet published in the open literature. Some of the other modelers are also finding more favorable comparisons with the higher quality 1980 observations of wet deposition. While encouraging, these comparisons are for the combined effect of all sources, and do not document the accuracy of models in simulating the effect of souce regions or individual sources. Most of our disagreements as to the value of models arise because we have not yet developed the capability to evaluate transport and deposition models exercised for single sources or source areas of pollutant sulfur over regional scales.

In assessment of potential emission control policies, atmospheric transport and deposition modeling is the link between estimates of emission changes and estimates of associated ecological, material, health, and aesthetic effects. For this role the transport and deposition model must be able to utilize emission information on the temporal and spatial scales of the policy analyst—usually no finer than annual and statewide but sometimes seasonal and/or point source—and be able to simulate deposition changes of the proper variables (e.g., total sulfate or pH) and time/space scales meaningful to the dose/response functions of effects researchers. Since assessment is generally for potential future conditions, there is considerable uncertainty in all aspects of the assessment, including meteorological conditions and emission levels. The detailed data required for sophisticated models under development will be gathered in diagnostic field studies, but future conditions cannot be determined to the same degree.

Often in assessment of potential emission changes for a single source, it is the deposition impact of the emission change relative to the deposition from all sources that is important, not the absolute impact. This is due to the fact that the absolute deposition associated with a single source several hundred kilometers downstream from that source may be too small to indicate a significant response in dose/response functions, even if the total deposition at that downstream location is ecologically damaging, because the contributions of hundreds of point sources are combined. Fortunately deposition models are believed to be more accurate in simulating relative deposition than in simulating absolute deposition, because common uncertainties in modeling may cancel in assessment of relative impact.

If we are not willing to apply state-of-the-art models of transport and deposition of air pollution in assessment of potential acid deposition policies, we cannot perform complete assessments today. If we do not perform assessments, there is no coherent method to weigh the costs of emission controls or disruptions in employment in the coal mining sector against the benefits of reductions in the levels of acid deposition. While I am fully aware that our assessment capabilities and accuracy will improve with time, it is my firm belief that we can perform useful assessments now.

Even though current models of transport and deposition contain large uncertainties, emission control policies that consider current estimates of source/receptor relationships are likely to be considerably more cost effective than emission control policies determined without regard to such admittedly imperfect source/receptor relationships. As a deposition reduction goal becomes more highly focused spatially (e.g., the Adirondacks instead of all sensitive areas) the cost effectiveness of a strategy considering source/receptor relationships increases markedly.

The key to a targeted approach to alleviation of the problems of acid deposition is definition of the target. The most cost effective control strategy for a 50% reduction in acid deposition in the Adirondacks is not going to be the same strategy as the optimal strategy for a 50% reduction in all ecologically sensitive areas, nor the same as an optimal strategy for maintaining wet deposition levels below 20 kg sulfate per hectare per year.

Yet we can assess (in terms of deposition change) potential effectiveness of various regulatory options according to these or other goals.

If a large targeted emission reduction test of control strategies is mandated, there are significant potential difficulties in analysis of the results. The difficulties can be overcome with proper planning and with cooperation of industry and government. The greatest difficulty in determining the effect of an emission reduction of perhaps 15-20% regionally is that the natural variability of deposition processes (wet years, abnormal flow conditions, etc.) and the variability of actual emissions confound the deposition change associated with the mandated emission change. It is necessary to maintain a highly accurate emission inventory on a scale at least monthly. With the accurate emission data, archival of meteorological data in a manner convenient for use in models of transport and deposition, and more rapid analysis of precipitation chemistry and air quality data, state-of-the-art models of transport and deposition can be exercised to produce monthly deposition patterns which can be compared with the observations. The model intercomparisons with data can quantify model accuracy or uncertainty. The verified models can then be exercised with the same time series of meteorological data but with the initial or unchanged emissions, and the differences between the simulations with reduced emissions and the simulations with initial emissions are then attributable to the emissions control policies.

The NRC committee is correct in advising caution in the use of current source/receptor models. Model limitations should be considered, and indeed are considered, in proper assessment. However, if the recommendation of caution implies a recommendation that current models not be utilized in policy analysis and determination, or that no emission control action be taken until some future date at which time better or more sophisticated models are available, then I strongly disagree. We can perform useful modeling exercises now, and the results of such exercises should be available to those who must determine whether to mandate emission controls, and if so, where and when.

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14 November 1983

Senator Max Baucus
United States Senate
Washington, DC 20510

Dear Senator Baucus:

You have asked me to respond to the following "acid rain" questions:

> Do we presently have enough evidence and detail in our models to design an efficient control strategy? Can it be done in simple terms, and if not, what further assessment would be necessary, and how long would it take?

Current or state-of-the-art models of atmospheric transport and deposition can be used to design an emission control strategy that is far more effective and efficient than a uniform rollback of emissions, but it cannot be demonstrated that such an exercise will select the most effective strategy. Indeed, even if source/receptor relationships for transport and deposition were completely known and perfectly produced by a model (a goal which numerical weather forecasting experience demonstrates will never be fully reached), our imperfect knowledge of ecological, structural damage, and health effects would still limit policy analysis.

As one who has developed and applied one of the state-of-the-art models of atmospheric transport and deposition, I have a favorable bias toward such models. Others, as in the National Research Council Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation, may disagree with my opinions and may hold, quite properly, that the accuracy of current models is undocumented and not well known. It is, however, quite likely that a consensus could be gained for the view that current models can be used to

US Department of Energy The University of Chicago

design a large-scale targetted emission reduction test. For example, such a test could take place if the control strategy mentioned in media accounts of the as yet unreleased recommendations of the Environmental Protection Agency Administrator were adopted. An initial reduction of 3 to 4 million tons of sulfur dioxide, designed both to minimize control costs and to maximize reduction of sulfur deposition in the Adirondacks and New England, could serve as a valid scientific test of the control policies, provided that meteorological variability and emission variability unrelated to the legislative action were properly taken into account. I have discussed a method to account for natural variability in the first attachment to this letter; the need for improved, near "real time" emission data is being discussed in the National Acid Precipitation Assessment Plan. A successful experiment could be the basis for an emission control policy of greater extent, should it be found necessary.

Considerable research has been carried out at Argonne National Laboratory, primarily by Dr. David Streets, to examine the direct costs and deposition reduction benefits of several Congressional approaches to ameliorate the acid deposition problem. Of greater interest, Dr. Streets' work has also produced theoretical modification of these approaches which could both minimize costs and maximize sulfur deposition reduction. His results, summarized in the second attachment to this letter, indicate that a focussed emission reduction could be designed for only a fraction of the cost of an essentially uniform rollback, provided intrastate and interstate trading of emission control actions is allowed. It is likely that interstate trading would be voluntary only in case of a Superfund approach, as in several of the legislative proposals.

The study by Streets et al. in the second attachment evaluates the cost of both intrastate and interstate trading, but evaluates the deposition reduction change only from interstate trading. For states near the considered receptor region, in particular, deposition changes resulting from intrastate trading could also be usefully evaluated. For instance, the deposition in the Adirondacks resulting from sources of similar character and strength in Buffalo, Syracuse, and New York City can be significantly different, and is estimable. In addition, the effective emission heights of sources involved in intrastate and interstate trading can also be considered in deposition reduction calculations. If other factors remain the same, there is more deposition reduction benefit to be gained in the Adirondacks from controlling sources in Ohio with tall stacks than can be obtained by controlling short-stack sources there, because the short stacks lead to more local dry deposition and thus less long-range transport.

Improvement of assessment capabilities is a gradual process. The current program of the Acid Deposition Assessment Staff of the Interagency Task Force, involving application of the growing body of research findings in many disciplines, is well constructed. In the future, we will be able to perform more accurate and more complete assessments, estimating both direct and indirect costs and both direct and ancillary benefits. Thus, we are developing a growing capability to design more efficient strategies. Unfortunately, currently no one can quantify with certainty the relative advantage of a later, more scientifically based and presumably more efficient emission control action, as compared to the ecological and other costs incurred by a delay in imposing that control. The targetted emission control test may be the best balance between reduction of a perceived impact and consumer costs of control action available to us this time. For the approach to be effective, the sensitive receptor targets must be specified, as well as any constraints on interstate and interstate trading, and on fuel gas desulfurization vs. fuel switching. In addition, it must be understood that observed reductions in deposition, both wet and dry, of total oxides of sulfur and nitrogen achievable by the test must be acceptable as a surrogate for benefits in the form of reduced health, ecological, and structural impacts. These would require decades of monitoring for certain detection.

The use of the result of a single model of atmospheric long-range transport and deposition in policy analysis has significant advantages over the use of the average results of a group of models. My experience has been that the range of results and implied uncertainty for a group of models can be artifically inflated if one or two of the models are inferior to the others. Further, the uncertainty in the results of a single model is much easier to evaluate than the uncertainty in a group of models, because the uncertainties related to specific atmospheric processes can often be isolated with individual models. In any case, since current models exhibit much more agreement in estimating the relative impact of particular source areas (or the relative efficacy of proposed strategies), than they do in evaluating an absolute impact, the differences in control strategy design derived from exercise of different models would not be as large as one might expect from some published model comparisons.

Sincerely,

Jack D. Shannon

Jack D. Shannon
Atmospheric Physics Program
Environmental Research Division

JD:rs
Enclosures

CONSIDERATIONS ON THE EFFECTS OF A LONG-TERM EMISSION REDUCTION TEST ON SULFUR DEPOSITION

Jack D. Shannon
Environmental Research Division
Argonne National Laboratory, Argonne, IL 60439

One of the policy options related to acid rain that has recently been proposed is a moderate emission reduction, perhaps four million tonne of SO_2, followed by a study to see if the action leads to a proportional reduction in sulfur deposition. While this proposal would have the obvious merit of assessing directly the effectiveness of a policy of emission reduction, there could be difficulties in interpretation of the results unless the deposition variations associated with the mandated emission reduction can be clearly separated from the deposition variations associated with other causes such as meteorological variability or with emissions variations not associated with the legislation.

One component of the National Acid Precipitation Assessment Plan calls for the periodic preparation of detailed emission inventories as required by the schedule of interim assessment activities. In general, such inventories are somewhat "smeared" in time, because of irregular updating by states or other reporting agencies. Further, they contain only average or anticipated seasonal variations, rather than actual variations for a particular period, such as our July, 1983, heat wave. It would be highly desirable to prepare sets of monthly emission inventories from the beginning of the emission reductions through the end of the test period. In addition to the mandated changes as they take effect, these inventories would be expected to reflect the emission fluctuations associated with short-term changes in electrical power demand, industrial activity, unscheduled plant outages, and the like. It would be just as important to have accurate data for Canadian sources as for United States sources.

Although it would be extremely difficult to obtain accurate monthly data on minor sources such as residential heating, it should be possible to obtain detailed power plant emission data over short time scales, particularly if the cooperation of industry research groups such as the Electric Power Research Institute is enlisted. The goal would be to create a data file of actual monthly North American SO_x and NO_x emissions for perhaps five to six years, including the period of time over which emission reductions are implemented.

It would be possible to estimate meteorologically induced deposition variability only with source/receptor models, since we do not and will not have a baseline record from a network of deposition collectors for a number of years during which emissions are unchanged. The uncertainty of at least some of the models in simulating deposition from all sources would be firmly quantified before the test period would be over, but quantification of the uncertainty in simulation of the deposition associated with specified source regions depends upon the success of several field experiments still in the planning stage.

The particular model or models to be exercised to estimate meteorologically induced deposition variation need not be selected beforehand. Fortunately, since the input data requirements for most candidate models are quite similar, the meteorological data that the models would require could be archived in a convenient form. Upper air wind and temperature data are already organized synoptically (all stations at each time) on a routine monthly basis. The routine archiving mode for surface data (by station) is unsuitable for direct use in models. The specific surface meteorological data required by a source/receptor model is a function of the model's complexity, but it seems likely that a standard, synoptic organization of surface weather reports and precipitation reports could be arranged.

United States and Canadian meteorological data should be merged into one data set.

The final result of the data organization would be monthly files of emissions, upper air wind and temperatures, and surface meteorological reports organized by time for all stations rather than by station for all times. Since digitization of radar and cloud observations is increasing, there is a possibility that such data could also be included in synoptic form in anticipation of improved models that could use it.

An additional area of concern is the observation of deposition. Wet deposition networks now operating or planned measure the proper variables, and provide adequate spatial coverage on a weekly schedule, but the time lag between measurement and release of seasonal data summaries is currently about two years. This could be decreased with increased support. Direct monitoring of dry deposition is somewhat problematical, since methods suitable for routine operations are still under development. If practical monitoring procedures are not developed in time, then a network of air quality sensors, capable of measurements at low concentrations, should be installed at regionally representative sites across North America. It has been shown that such data, plus some knowledge of the site characteristics and the prevailing weather conditions can be interpreted in terms of dry deposition rates.

The source/receptor model or models could be exercised with the monthly meteorological data sets and monthly emission data sets to produce monthly deposition estimates, which could then be compared with the monthly totals of the weekly observations. These comparisons would objectively evaluate uncertainty in model simulations. The models would also be run with the monthly meteorological data but with the pre-reduction emissions, with expected seasonal variations. These simulations of "no-action" deposition could then be subtracted from the simulations of deposition with actual emissions to provide monthly estimates of the efficacy of the mandated emission changes. Relations between the deposition changes and emission changes would then be examined in a statistical manner, making use of modeling uncertainty and emission uncertainty estimates derived in the process. An attractive by-product of the high temporal and spatial resolution of the emission and deposition data would be that source/receptor relationships could be quantified observationally to some extent.

I wish to emphasize that these concepts do not require selection of a model or modeling approach before the emission reduction test. As long as the proper data are gathered in a timely and accurate manner and organized in a manner convenient for use, any reasonably accurate transport and deposition modeling approach could be used. The accuracy of the approach would be given by the comparison with observations. I have emphasized deposition reduction as a measure of effectiveness rather than a decrease in environmental damage because of the greater uncertainties and longer time lags in biological systems.

DRAFT

TARGETED STRATEGIES FOR CONTROL OF ACIDIC DEPOSITION

by

D.G. Streets, D.A. Hanson, and L.A. Conley

Energy and Environmental Systems Division
Argonne National Laboratory

October 1983

SUMMARY

Most of the programs proposed to date to control acidic deposition do not appear to consider the relative costs of achieving emission reductions in different states nor the relative contributions of emissions in different states to acidic deposition at sensitive receptor sites. This may be because control cost models and atmospheric transport models are not presently verifiable to a degree necessary to support confident conclusions about the effects of emission control strategies. However, these models can be usefully employed to discern relative merit among different strategies, at broad levels of source/receptor aggregation.

The purpose of this analysis is to show that, if one acknowledges the considerable uncertainty associated with currently available tools, control strategies can be designed to achieve specific objectives with considerably improved efficiency compared to the strategies under consideration by Congress. In particular, this analysis examines cost-effective strategies to minimize acidic deposition in certain "targeted" regions that are considered vulnerable to acidic deposition.

In an effort to demonstrate the potential economies achievable by applying a targeted approach to control, several versions of the two Senate Bills S.768 and S.769 are evaluated in terms of annual control costs, SO_2 emission reductions, and sulfur deposition rates in nine sensitive regions. The sensitive regions are: Boundary Waters, Algoma, Muskoka, Quebec, Southern Nova Scotia, Vermont/New Hampshire, Adirondacks, Pennsylvania, and the Smoky Mountains.

The results are striking. The control measures proposed in the legislation (assuming intrastate emissions trading) are relatively expensive because of the economically inefficient allocation of emission reductions

among the states. Regional cost optimization over the eastern U.S. (interstate emissions trading) can reduce costs by more than 50%. Regional cost optimization also increases the deposition reduction achieved in critical sensitive areas.

A targeted approach to control is analyzed that would achieve the same reduction in sulfur deposition in one of the most critical sensitive regions, the Adirondacks, as the bills would achieve, at minimum cost. This could lower the cost of achieving that level of deposition reduction in the Adirondacks by between 75 and 90%, with the estimate depending upon which of several atmospheric transport models are used.

The targeted strategy designed to reduce sulfur deposition in the Adirondacks at minimum cost is also effective at reducing deposition in other sensitive regions in the northeastern U.S. and southeastern Canada. However, this approach does not yield as great a deposition reduction in the Boundary Waters, Algoma, and Smoky Mountains regions as do the legislative proposals. This may not be critical in the near future for the first two of these areas, because current deposition rates are relatively low. The Smoky Mountains, on the other hand, might merit a second targeted strategy, because deposition rates are relatively high there.

The targeted strategy is sensitive to meteorological variability. A factor of two difference in control costs resulted from model runs which used meteorology from two different time periods. Meteorological variability in areas close to the sensitive receptor regions is particularly important.

Targeted strategies can also be designed to meet multiple objectives, such as achieving desired reductions in deposition in many sensitive regions at minimum cost. This analysis shows that wet deposition of sulfate can be reduced to levels below the value recommended by a number of scientists, 20 kg

ha^{-1} yr^{-1}, in all nine of the sensitive regions, at a cost slightly less than the cost of an unoptimized S.769. A target of 30 kg ha^{-1} yr^{-1} can be achieved in all sensitive regions with approximately an 80% reduction in control costs compared to S.769 and the 20 kg targeted option.

The control costs evaluated in this analysis assume that fuel switching is an allowable option for electric utilities to achieve emission reductions, in addition to technological control methods (use of flue gas desulfurization) and coal washing. Fuel switching, however, has the potential to disrupt established markets of coal supply, causing miner dislocation and secondary cost impacts. To avoid these impacts, control programs have been proposed that would necessitate the use of flue gas desulfurization technology alone to achieve the required emission reductions. This analysis shows that costs would increase by 6-21%, depending upon the control strategy considered, if fuel switching is not a permissible compliance option.

In conclusion, this analysis indicates that, if reducing sulfur deposition in the northeastern U.S. and southeastern Canada is the primary objective of an acid deposition control program, then there is a large potential for cost savings by using a targeted approach. The quantitative findings of the study are summarized in the following table.

Summary Table

Strategy	Annual Cost[a] ($ billion)	Reduction in Annual SO_2 Emissions[b] (million tons)	Reduction in Total Sulfur Deposition[c] in the Adirondacks (%)
S.768			
Intrastate Trading	4.2	9.0	23 (21-26)
Interstate Trading	1.9	9.0	26 (26-31)
Deposition Optimized	0.9 (0.4-1.1)	5.0 (1.9-5.5)	23 (21-26)
Intrastate (FGD only)	4.6	9.0	23
Interstate (FGD only)	2.3	9.0	27
S.769			
Intrastate Trading	12.9	14.9	40 (38-46)
Interstate Trading	6.0	15.0	46 (45-57)
Deposition Optimized	3.0 (1.3-3.2)	9.8 (4.2-10.3)	40 (39-46)
Intrastate (FGD only)	13.6	14.9	40
Interstate (FGD only)	7.0	15.0	47
20 kg Target[d] Loading	11.9	16.2	56
30 kg Target[d] Loading	2.5	9.4	29

Numbers in parentheses represent a range of results for six atmospheric transport models.

[a] In real, levelized 1980 dollars
[b] In English short tons
[c] Modeled using ASTRAP with 1980 meteorological data
[d] Measured in kg ha^{-1} yr^{-1} of wet sulfate

Note: Costs are optimized using the techniques described in the appendices. Real-world costs would be expected to be greater than these theoretical least costs.

JULIE/DEBORAH
ENVIRONMENT
Acid Rain
KB

November 3, 1983

Dr. Michael Oppenheimer
Senior Scientist
Environmental Defense Fund
444 Park Avenue South
New York, New York 10016

Dear Dr. Oppenheimer,

Thank you for attending the hearing of the Environment and Public Works Committee and providing testimony on the problem of acid deposition. I have some further questions that I would like to ask you for the record.

You have stated that in the peer review literature no evidence of non-linearity has been presented for the macroscale process. Has it been determined that the macro is the correct scale to be working at in designing a control strategy?

Are the simplified models of long-term and large-scale averages adequate representations for this purpose?

I look forward to your prompt reply.

With best personal regards, I am

Sincerely yours,

ENVIRONMENTAL DEFENSE FUND

November 9, 1983

Senator Max Baucus
United States Senate
Washington, D.C. 20510

Dear Senator Baucus:

In response to your letter of November 3, I would submit the following points for your consideration:

1. I stated that no evidence of macro scale non-linearity in Eastern North America has been presented in the peer-reviewed literature, and that the European data is too limited to allow any conclusions to be drawn on this subject. By macro scale, I mean scales measured by precipitation monitoring networks rather than laboratory experiments on atoms and molecules. As a practical matter, it is irrelevant to policy considerations if particular molecular interactions are non-linear as long as these interactions aggregate to be effectively linear with regard to deposition measurements. That is, as long as reductions in emissions lead to proportional reductions in measured deposition over the course of weeks, months, or years, the overall acid deposition process may be said to be "linear" as far as ecosystems are concerned.

2. Current models are reasonably accurate for predicting deposition over the course of months on scales of a hundred miles squared or so. There is no evidence that smaller time scales are biologically important. With regard to smaller distance scales, it may be desirable to understand deposition response to emissions changes on a smaller scale, but for the purpose of predicting the effect of large scale regional sulfur controls

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involving many sources, model predictions on a smaller scale will provide little additional information.

Sincerely,

Michael Oppenheimer
Senior Scientist

MO/la

Submitted for the record by Dr. Oppenheimer

NON-LINEARITY AND THE EUROPEAN DATA

As reported in the National Academy of Science study on Acid Deposition, the only direct evidence of non-linearity in the transformation of sulfur dioxide to sulfuric acid in rain comes from data gathered in Europe. That data, discussed by Granat, [1] indicates that doubling in sulfur dioxide emissions between 1955 and 1972 was accompanied by little change in wet sulfur deposition. This observation has been put forward as evidence of non-linearity in the transformation of SO_2 to acid rain since changes in SO_2 emissions are not accompanied by concomitant changes in acid rain. There are two major flaws in this argument:

1. The precipitation network used to monitor wet deposition was confined to Northwestern Europe (see attached figure), while emissions were tabulated for the European continent in general. Changes in the distribution of emissions over the period could easily have caused emissions to increase in areas far removed from Northwest Europe. In that case, emissions increases may not be reflected in deposition increases in the network. Deposition in the network could be stable or decrease while total emissions increase, regardless of the degree of linearity of transformation.
2. Changes in stack heights could cause less sulfur to be deposited within the network and more outside, even with generally increasing emissions, and even if the relative distribution of emissions remained constant. This interpretation was suggested in Granat's paper.

Therefore, absent a more extensive precipitation network, the European data contains no evidence of non-linearity.

The precipitation data was interpreted by Rodhe [2] using a crude model for atmospheric chemistry. The model contained a theoretical non-linearity and was able to reproduce observed sulfate to nitrate ratios. This agreement was used to substantiate the model. However, the model has subsequently been shown to be inadequate for a number of reasons. It simply does not accurately represent atmospheric sulfur chemistry. The Academy report analyzes the defects in its non-linear representation of gas phase chemistry. In addition, the model's non-linear representation of cloud chemistry is totally deficient because it includes only one reaction. Therefore, any predictions of non-linearity made by the model are suspect and comparison of its predictions with the European observations cannot be taken as evidence of non-linear chemistry.

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1. L. Granat (1978), Atmos. Environ. 12, 413.

2. H. Rodhe, P. Crutzen, and A. Vanderpol (1981), Tellus, 33, 132.

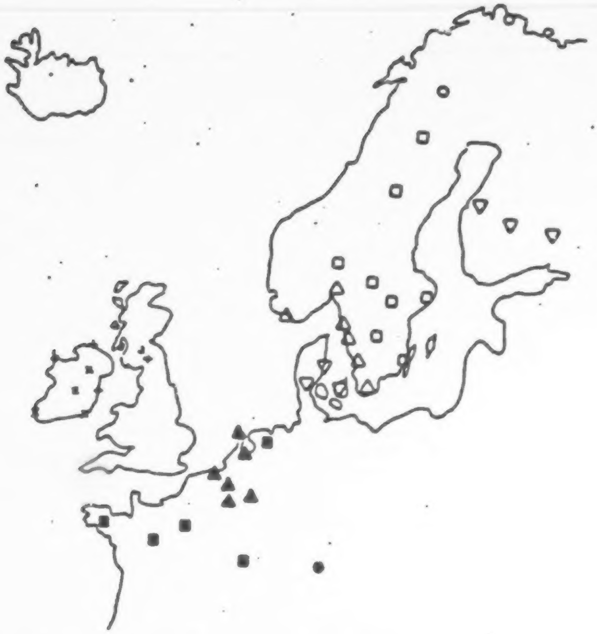

Fig. 6. An indication of areas with different patterns in long term temporal variation of sulfate concentration/deposition. Symbols refer to groups of stations according to Figs. 4 and 5.

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21 November 1983

Senator Robert T. Stafford, Chairman
Senate Committee on Environment and Public Works
Dirksen Senate Office Building, Room 410
Washington, D. C. 46176

Dear Senator Stafford:

As Chairman of the recent Committee on Acid Deposition of the National Research Council, I am sorry that I was unable to attend the recent hearing on acid rain which was held under your leadership on November 2, 1983. Dr. Myron Uman, the NRC Staff Officer for our NRC Committee on Acid Deposition, represented our NRC Committee. I have a copy of his testimony and concur with his comments. However, I note that Bernard Manowitz presented at the same hearing a testimony questioning some aspects of our report; in particular he presented an updated version of an informal "review" of our NRC report which was carried out by selected representatives of several national laboratories supported by the Department of Energy. Manowitz attempted to answer questions which we have raised concerning the scientific accuracy of the Manowitz "review," but his current response and that of his colleagues, Lipfert, Slinn, and Tian (consultant), have not addressed satisfactorily our concerns. It is important that our comments be included in the hearing record along with the original Manowitz review which was sent to the National Academy of Sciences, to me, to various members of the Interagency Task Force on Acid Rain and others; my friends in industry and government tell me that the report was widely circulated to the leadership and research arms of the power industry and related industrial operations throughout the United States and within the extensive communications pipeline of the administrative and legislative staffs of the Federal and State governments. His original "report" has subsequently been sanitized and presented to your committee with a few additional comments added by others.

Allan Lazrus and I have responded to the original "report" of Manowitz on behalf of our committee members. This response was given in my testimony to the House Committee on Science and Technology, September 13, 1983, and I have attached it to this letter as Appendix A. Since these comments refer to the Manowitz "report" as originally circulated widely, we have attached as well a copy of this, labeled Appendix B. The recent modified version of this report now submitted by Manowitz speaks to the same basic questions which are in the original report, and our comments still apply. The moving target which Manowitz generates in his many reports is most disconcerting, and to avoid further time consuming effort on this scientifically incorrect and uncalled for "review," we will stick with our comments based upon the widely circulated original version. The points 5, 6, and 7 which Manowitz indicates we did not answer, were not included in the original version. They are relatively trivial and need not be discussed here.

From the response to our criticism by Manowitz and his colleagues, I can find little evidence that Manowitz et al. have read our report carefully or that they understand our comments and criticisms of their "report." Their comments presented to your committee remain scientifically flawed, and they do not justify further discussion by us. It is a shame that their new consultant (Tian) did not evaluate the so-called regression analysis which was carried out by Lipfert of the Manowitz group. His treatment of the Hubbard Brook data is obviously in error. On the basis of what is now known about transport to the Hubbard Brook region one cannot honestly attempt any such analysis, even if the basic errors introduced by Lipfert were avoided. Our qualitative treatment of the data is all that can now be made with these data.

In the interest of accuracy for the record of the November 2, 1983 hearing before your committee, I request that both the attached sections (labeled Appendix A and Appendix B) be added to complete the record.

Sincerely yours,

Jack Calvert

Jack G. Calvert
Senior Scientist
Chairman of NRC Committee on
Atmospheric Transport and
Chemical Transformation
in Acid Deposition

cc:Myron Uman
NRC Committee Members

Enclosures

JGC:mao

APPENDIX A: COMMENTS OF JACK G. CALVERT AND ALLAN LAZRUS ON THE INFORMAL "REVIEW" OF THE NRC COMMITTEE REPORT ON ACID DEPOSITION SUBMITTED BY BERNARD MANOWITZ GROUP

Recently we received a copy of a "review" of our NRC acid deposition report which was prepared under the guidance of Bernard Manowitz (Brookhaven National Laboratory) by selected representatives of three national laboratories supported by the Department of Energy: Brookhaven, Battelle Pacific Northwest, and Argonne. These "reviews" were sent to the National Academy of Sciences, to me, to various members of the Interagency Task Force on Acid Rain and others; my friends in industry and government tell me that the report was widely circulated to the leadership and research arms of the power industry and related industrial operations throughout the United States and within the extensive communications pipeline of the administrative and legislative staffs of the Federal and State governments. The original report has subsequently been sanitized and additional comments added from a group at Oak Ridge National Laboratory. This revised report was presented to Representatives Fuqua, Scheuer, and Lloyd of the House Science and Technology Committee previously (September 13, 1983), and it was included, with some further changes, in the recent hearing of Senator Robert T. Stafford's Committee on Environment and Public Works (November 2. 1983). These revised versions do not differ greatly from the original version as far as the basic science questions raised, so we will respond to the original "review" which has received wide circulation. I have enclosed in Appendix B of this report a copy of the original Manowitz group "review."

The comments given here represent those of only two of our NRC acid deposition committee, myself (Jack G. Calvert) and Allan Lazrus, since time did not allow the participation of the entire committee. A Congressional hearing or the Congressional Record is not well suited to scientific debate. In the long run scientific issues cannot be influenced by legal or legislative actions or by pressures from business, conservation groups or other special interest groups, including that headed by Manowitz. Indeed the scientific world does not accept blindly the stated opinions of any scientist or group of scientists, including the NRC committee on acid deposition, without extensive testing and checking of the ideas proposed. Fortunately for science the issues will be decided after extensive research and suitable discussions in the refereed scientific literature. However, I feel that the Manowitz group and its "review" cannot be disregarded by me since it has been presented to a wide and important audience as a scientific endeavor which disputes some key aspects of the NRC acid rain report. Although it is difficult to sort out the science from the rhetoric in some of these "reviews", we will focus on what we judge to be the important scientific questions which have been raised.

First, our use of the Hubbard Brook acid deposition data and the subsequent conclusions which we derived from them have been questioned. It is claimed by reviewer D that he has treated these and other data not available to the scientific community, in a more rigorous scientific fashion that did we. He concludes from this treatment that there is no 1:1 proportionality between sulfur oxide emissions and sulfate deposition at Hubbard Brook. Let me say at the outset that reviewer D is working with a set of data which have not been available to our committee. We had access only to the monthly averages which were reported in the preliminary writings of the Interagency Task Force on Acid Rain. Furthermore, we received only a preliminary version of the recent study edited by Munn of the University of Toronto (1982); this was designated by reviewer D as part of the extensive discussion and analysis of Hubbard Brook data available today, although it has not been published or released to our knowledge and appears to be in very rough form. We were requested not to quote or use this report in our considerations because of its preliminary nature.

Our response to reviewer D's comments are not altered by these complicating factors.

The arguments of reviewer D are seriously flawed scientifically for several reasons. He does not provide any evidence that justifies the variables employed in his multiple linear regression analysis; in fact, one of these was clearly inappropriate (his "wave" function). In reviewer D's treatment the actual observed sulfate values have been radically altered by "theoretical" adjustments of the original data. These adjustments are simply the results of multiple linear regression equations using three variables: the period of the year, surface temperature at a site miles from Hubbard Brook, and the amount of precipitation at Hubbard Brook. The corresponding regression coefficients, for which statistical significance is not demonstrated, are ambiguous.

a) Although the time of the year affects the extent of sunlight and oxidant generation, it has also been shown in work by Tanner and Leaderer (1982) to influence the contribution of long-range transport to sulfate in aerosols.

b) Though there is only one correction term for precipitation, it has been clearly demonstrated at Hubbard Brook that different types of storms manifest different relationships between the amount of precipitation and the concentration of sulfate. See the NRC report on acid deposition, p. 110-111. Increased precipitation during convective storms tends not to significantly decrease sulfate concentration, while in the case of warm frontal precipitation, sulfate concentration is inversely related to the volume of precipitation because of dilution (Munn, et al., 1982). On a climatic basis, an increase in frequency of storms may not have a significant impact on concentrations, whereas larger storms, depositing more water, may be inversely related to sulfate concentrations A single regression coefficient cannot meaningfully account for these complex effects.

c) The temperatures employed by reviewer D are monthly averages collected at a location 75 miles from Hubbard Brook. Data from weekly precipitation samples were regressed against monthly averaged temperatures, even though there is no model based on physical and chemical principles which is capable of realistically relating surface temperatures to the incorporation of sulfate in rain.

The square of the correlation coefficient is a measure of how much variance in sulfate concentrations is attributable to the variance of sulfur dioxide emissions. Reviewer D's treatment of the data appears to be an attempted mathematical reduction of the variance of the data, with the likely intent of removing portions of the variance not dependent on sulfur oxide emissions. However the parameters selected to accomplish this goal are themselves not physically unrelated to sulfur oxide emissions or to the transport of sulfur oxide emissions to remote sites. The data adjustments applied by reviewer D are on the one hand likely to remove some variance related to sulfur dioxide since the parameters used are related to sulfur dioxide emissions. On the other hand if these are inappropriate variables for the adjustment, then they will lead to nothing but an increase in the error component in the adjusted sulfate record. One must question the effectiveness of the adjustment when the mean for the adjusted record is 42% greater than that actually observed at Hubbard Brook. It is very important to note that reviewer D's weighted estimates of annual averages of sulfur dioxide emissions do correlate at the 95% confidence level with the annual average sulfate concentrations reported by Likens. After "adjustment" of the actual data by reviewer D, there is no correlation. The correlation coefficient is no longer statistically different from zero or negative values. The data "adjustment" is not justified.

In our view there is a second major error in reviewer D's statistical treatment. In order to "correct" the observed data he models the long-range transport of sulfur dioxide in a most unrealistic way. Based upon the failure to detect a strong correlation between local wind direction and sulfate observed in precipitation at Hubbard Brook, reviewer D surmised that sources from all directions can effect Hubbard Brook depositions equally and that their impacts are functions of the source strength and source distance alone. This is not an acceptable hypothesis. Furthermore reviewer D has chosen to use as representative of Hubbard Brook the local wind directions from a distant station on the coast of Maine, about 100 miles from Hubbard Brook, New Hampshire. A great many studies have shown the error in the use of even the actual local wind directions as an indicator of source region for long-range transport. In fact, the calculation of back trajectories of air parcels which bring precipitation to Hubbard Brook, suggest that less than 10% of the air masses come from the Midwest or EPA Region V (Munn, et al., 1983). Since the emission rates for sulfur dioxide in Region V are very much greater than the emission rates for regions I or II (New England), but the distance from Hubbard Brook to the centroid of emissions in Region V is only several-times greater than that of regions I or II, the contribution of the Midwest in reviewer D's model is comparable to that of the Northeast. This is totally inconsistent with the actual air parcel trajectory analyses. Since SO_2 emissions in Region V vary differently with year than in Regions I and II, the correlation analysis will be distorted. Thus the lack of statistically significant correlation between reviewer D's calculated sulfur dioxide parameters and any other variable is quite meaningless in view of Munn's trajectory study. Furthermore both the NRC acid deposition committee report and the full report of the Interagency Task Force on Acid Rain state that no present model describes in a quantitative fashion the relative impact of sulfur dioxide sources as a function of their strength and distance. Given the lack of such reliable models, it is not scientifically sound to attempt the treatment of SO_2 emissions and sulfate concentration at remote sites given by reviewer D.

The conclusion of the NRC committee, namely that a large decrease in sulfate deposition at Hubbard Brook corresponded in time with a large decrease in sulfur dioxide emissions in the northeast, is as definitive a statement as was permitted by the data. Certainly the attempt to be more quantitative made by reviewer D is seriously flawed scientifically, and it must be rejected.

His treatment of sulfate to nitrate ratios which appears in the revised version suffers from the same problems, and the results are of uncertain quality. Reviewer D is critical because of the inexact correspondence between the molar ratios of SO_2/NO_x in emissions and $SO_4^=/NO_3^-$ in wet deposition. However the report recognizes the discrepancies and deals with them in the following excerpt from this report:

> It is surprising to note in addition that the annually averaged molar ratios in precipitation at the MAP3S, NADP, and CANSAP sites in eastern North America resemble the molar ratios of SO_2 to NO_x emissions averaged on an annual basis by state or province (Figure 4.18). The emission ratios are somewhat higher than the deposition ratios in the Ohio and Tennessee River Valleys. Similarly, the emission ratios are somewhat lower than the low deposition ratios immediately north of Lake Ontario. The smaller spatial variability of the deposition ratios compared with the emission ratios near large point sources is probably related to a rapid rate of atmospheric mixing relative to the rates of wet-deposition processes. Alternatively, a preferential dry deposition of SO_2 relative to that of NO_2 may occur in the near-source region, or the differences may indeed represent a suppression of SO_2 oxidation within a short distance from the emission sources. However, the general similarity of wet-deposition and emission ratios on an annual average basis suggests that the incorporation of sulfuric acid in rain is not retarded with respect to the conversion and incorporation of nitric acid in rain.
>
> A small body of data suggests that the historical trends in the molar deposition ratios of sulfate to nitrate correspond to the trend in molar SO_2/NO_x emission ratios. The historical trends of the molar deposition ratio $SO_4^=/NO_3^-$ at Hubbard Brook and the molar ratios of SO_2 to NO_x in emissions in the eastern United States by EPA Region are plotted in Figure 4.19. Also shown in the figure is the result of a linear-regression analysis of the Hubbard Brook deposition ratio against time. Between 1965-1966 and 1979-1980, the linear regression gives a slope of -0.039 (standard error 0.006) and an intercept of 1.444 (standard error 0.054). The significance level of the slope is 0.0001.

> Another perspective is provided by comparing the annually averaged regional wet-deposition rates with regional emissions. Integrating wet deposition over the northeast quadrant of the United States [using the isopleths of Pack (1980) based on MAP3S and SURE data], Golomb (1983) found sulfate deposition to be 4.3×10^{10} (±20 percent) moles/year and total nitrate deposition to be 3.9×10^{10} (±25 percent) moles/year. Golomb calculated regional emissions from U.S./Canada (1981) to be 2.2×10^{11} moles/year of SO_2 and 1.8×10^{11} moles/year of NO_x. The emissions were similarly distributed geographically. Golomb also indicates that 19 ± 6 percent of the sulfur and 20 ± 7 percent of the nitrogen emitted in this region are wet deposited there. It is interesting to note that Golomb found the molar ratio of sulfate to nitrate wet deposited annually in this region to be 1.1, compared with an annually averaged molar ratio of emissions for SO_2 and NO_x of 1.2. The similarity of the ratios suggests that, whatever specific processes are taking place, there is a tendency on an annual basis for sulfate and nitrate to be deposited in the northeast quadrant of the United States with no significant loss of one component relative to the other.

When Reviewer D realizes that atmospheric mixing may be important, he resorts to simplistic hypothetical considerations of transport which are relatively meaningless.

Reviewer D is concerned with the large discrepancy between emissions and deposition ratios in the northern Canadian provinces. However, these large emission ratios (e.g., 30.96 for northern Quebec) are associated with only 560×10^{-3} tons of SO_2 per year in a region of about 480,000 square miles. In terms of average annual emissions of SO_2 per unit area, the northern Quebec region resembles Nebraska. The report restricted its comments regarding ratios to the region bounded on the north by the acidity isopleth of pH = 4.6. At lower acidities, it is not possible to discriminate between the effects of regional anthropogenic sources, imported sources, and natural sources on the $SO_4^{=}/NO_3^{-}$ ratio. The report maintains only that within the region of precipitation acidity higher than 4.6, i.e., clearly anthropogenic, there is no evidence of large scale nonlinearities.

Reviewer D maintains that an insignificant correlation exists between weekly $SO_4^{=}/NO_3^{-}$ ratios at Hubbard Brook and SO_2/NO_x emissions in Federal Regions I and II. It is not statistically feasible to compare weekly deposition ratios with annual emission ratios. If reviewer D adjusted the weekly values to obtain annual averages as he did in the case of sulfate concentrations, the results are of questionable relability.

Review E has written his comments with such an extraordinary degree of rancorous disdain that we are tempted to neglect his comments completely. The reviewer must have been driven by desperation to resort to such levels of distorted analysis. His approach is typified by the following salient argument copied from his review:

> 12. pp. 127-131. Here's what I want you to plot. Take the molar ratios for Europe (given in Table 4.7) and plot them against distance, say from your Region 1, and then add the data for N. America (your Fig. 4.17, p.130). Sure, it'll be crude:

Station	Distance (deg. lat.)	Ratio (normalized)
Europe:		
1	0	1
2	4	1.2 or .7
3	5	1.2 or 1.3
4	8	1.8 or 1.3
5	14	2.0 or 3.8
N. America:		
PA	0	1
Adirondacks	2	1.2
Quebec City (Your 1.6)	5	1.6

> OKAY, NOW PLOT THEM. NOW, WHAT WERE YOU GUYS SAYING ABOUT CONSTANT MOLAR RATIOS????????????
>
> This is so bad that even if I weren't out of time, I don't know how I could continue. Pure unsubstantiated bull! The opposite conclusion to theirs is staring them in the face!

Region I was selected by Rodhe et al. to represent the industrial source region, and in fact comprises the Ruhr Valley and the intensively industrialized area to the West of it. The other regions were chosen to represent downwind areas in which the average chemistry of the precipitation would reflect changes in the chemistry of the pollution plume as a function of distance from the source region. It is assumed that pollution sources enroute are not large enough to introduce large changes in the plume chemistry. The NRC acid deposition report examines the molar ratio of sulfate to nitrate in each of the regions to discern whether rapid consumption of oxidant by nitrogen oxides in the source region retards the oxidation of SO_2 until the plume travels to greater distances. The observed ratio increases with distance consistently with this hypothesis, but as the report states, there are other explanations. The report states however that the lack of a gradient in ratios is not consistent with the hypothesis, and in North America no gradient is apparent.

Reviewer E chooses to normalize the ratio of sulfate to nitrate to unity at the source of the region with the simple proportion: X/region ratio = 1.0/source ratio. However, it is clear from Figure 4.17 that the ratio is not increasing between Pennsylvania and the Adirondaks, and his normalized ratio should be 1.0 for the Adirondaks, not 1.2 as he indicates. The nearest station to Quebec City indicates an observed average of 1.3, or a normalized value of 1.2, not 1.6 as Reviewer E indicates.

A more serious distortion, however, arises from reviewer E's use of central Pennsylvania as the principal origin of a regional plume causing acid rain over North America. A more realistic comparison with the source region selected by Rodhe et al. would be the Ohio River Valley. In the attached copy of the NRC acid deposition report Figure 4.17, arcs are drawn from Cincinnati (a central location in the Ohio River Valley) corresponding to the linear distances between the center of each downwind region and the source region in the European map (Figure 4.16). Contrary to the table of reviewer E, the figure indicates that even at 8 degrees distance from the source region there is no indication of an increasing gradient of the ratio.

The NRC acid deposition report is limited to a discussion of $SO_4^{=}/NO_3^{-}$ ratios to regions where the pH is 4.6 or lower, since at higher pH values the ratio is probably influenced at least as much by local SO_2 sources, natural sources, or globally distributed, anthropogenic sources as by long range transport from the Ohio River Valley. At pH 5.0 the acidity is within the range of global background values (NRC acid deposition report, p. 13). The northernmost region in the European map was characterized by a $SO_4^{=}/NO_3^{-}$ molar ratio of 5.7, and was also typified by a pH of 4.6 in 1974 (Likens et al., 1979). However the analogous outermost arc on the attached version of Figure 4.17 lies at 1,150 miles from the source region. It falls in the region of pH 5.0 or higher in North America, and the ratio can no longer be realistically considered as reflecting principally chemical transformations in the original plume.

Referee E has implied that the gas phase chemistry is unimportant in acid deposition in northeastern North America. Sulfuric acid generation occurs in clouds and in gas phase reactions. Indeed evidence suggests that oxidation of sulfur dioxide in clouds in northeastern North America may be more important than that occurring in the gas phase. However the effective oxidants, ozone, hydrogen peroxide, and possibly other peroxy compounds, which are believed to be the necessary reactants for sulfur dioxide (bisulfite ion) in clouds, all are formed in gas phase chemistry. Thus in terms of current theory for clouds which have low concentrations of metal ion catalysts (Fe^{3+}, Mn^{2+}, etc.), if we don't

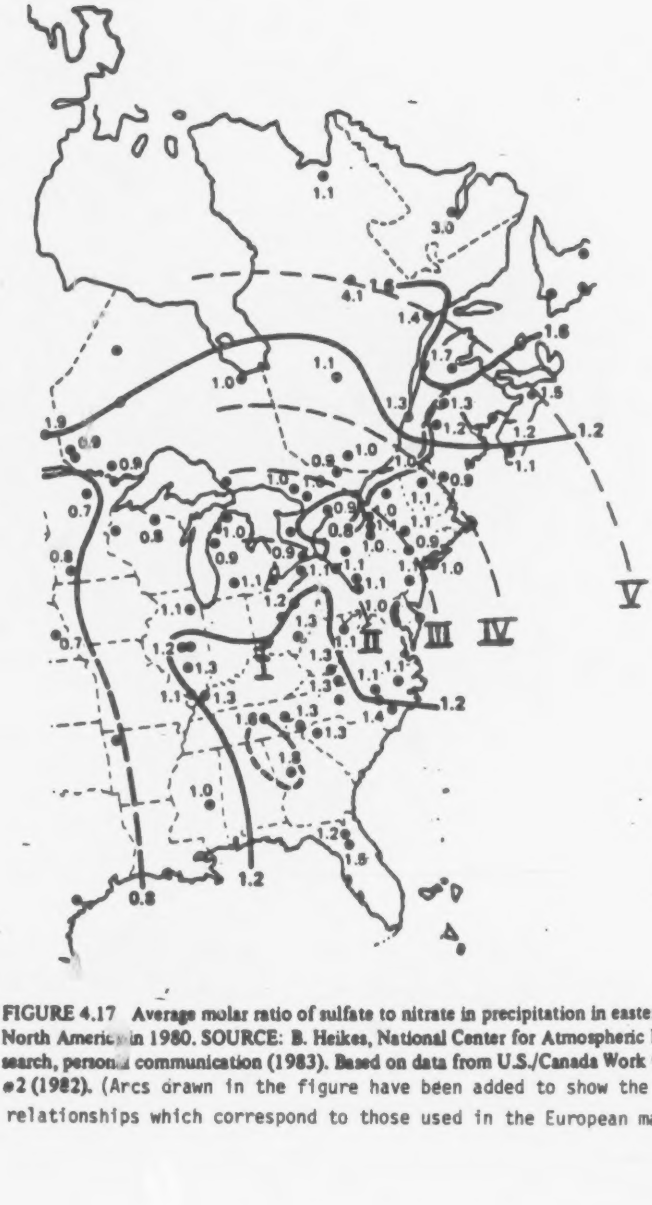
1.1
3.0
4.1
1.6
1.4
1.6
1.7
1.0
1.1
1.3
1.3
1.5
1.9
1.2
1.2
1.2
1.1
0.9
0.9
1.0
0.9
1.0
0.7
0.8
0.8
1.0
0.9
1.1
1.1
1.0
0.9
1.0
0.7
1.2
1.3
1.1
1.3
1.4
1.2
1.3
1.0
1.2
1.5
1.2
0.8
I
II
III
IV
V

FIGURE 4.17 Average molar ratio of sulfate to nitrate in precipitation in eastern North America in 1980. SOURCE: B. Heikes, National Center for Atmospheric Research, personal communication (1983). Based on data from U.S./Canada Work Group #2 (1982). (Arcs drawn in the figure have been added to show the distance relationships which correspond to those used in the European map; Fig. 4-16.

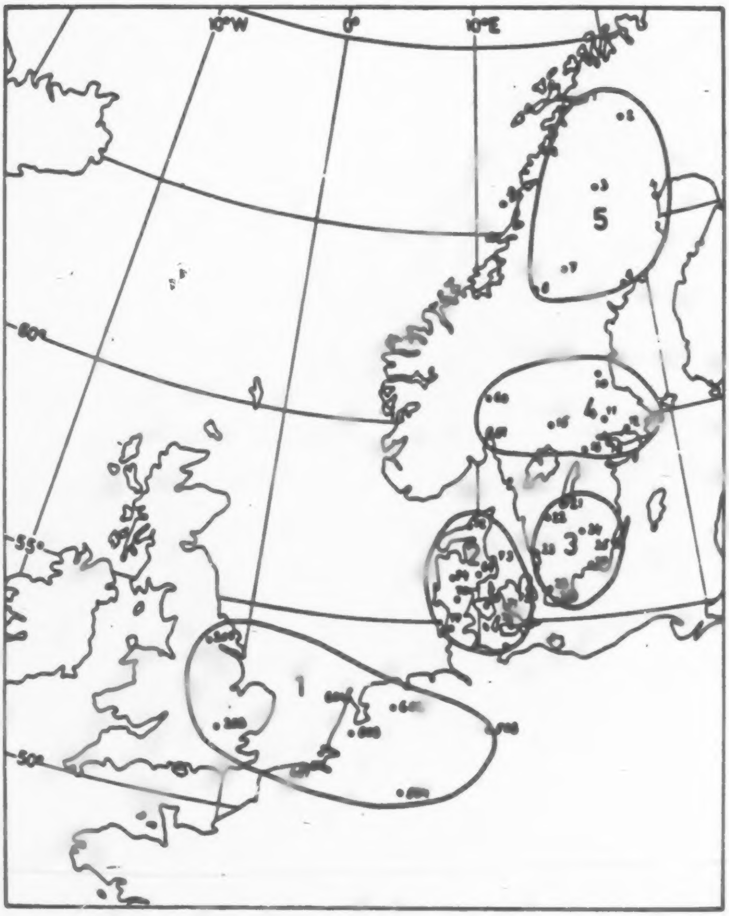
10°W
0°
10°E
60°
55°
50°
5
4
3
2
1

FIGURE 4.16 Locations of monitoring stations used in the data analysis of Table 4.7.
SOURCE: Rodhe et al. (1981).

include gas-phase chemistry we cannot account for the rapid rates of acid generation which have been observed to occur in clouds. Gas phase and solution phase reactions are highly coupled, and no scientist today would attempt to rationalize the chemistry involved in acid deposition without including both gas phase and solution phase processes.

One other important conclusion of our NRC acid deposition report has been questioned. We conclude that the reliability of long-range transport and transformation models is presently low in relating specific sources with receptor sites in sensitive areas. This conclusion does not seem to differ from that expressed in the report of the Interagency Task Force on Acid Rain (with which the Manowitz group has some undefined relationship), and the brief report of the Acid Rain Peer Review Panel. It also appears to be in accord with the comments of reviewer C (Bruce B. Hicks) of the newly added Oak Ridge "review" group. Work of Dr. Jack Shannon of Argonne National Laboratories has shown in very recent unpublished simulations using the ASTRAP model (private communication to Jack G. Calvert) that very good correlations are found for the calculated annual wet sulfate and nitrate deposition in eastern North America and the depositions observed in the 100 MAP3S, NADP, CANSAP, and APN sites for the year 1980. See the communication from Dr. Shannon in the attached letters in Appendix B. Such results look encouraging as related to long-time averages over a large area. It is interesting that a proportional or linear chemical model (with diurnally and seasonally varied rates of SO_2 oxidation), rejected by the Manowitz group, was employed in these seemingly successful long-term average simulations. A more important question at hand is how well present models can do in establishing the percentage of the deposition in a given sensitive area which can be ascribed to a given emission source and the extent of cutback in acid deposition in sensitive areas which we can expect from control of certain large sources which are well-removed from the site. It is the opinion of the NRC committee on acid deposition, the Interagency Task Force on Acid Rain, as well as the President's Panel on acid rain that this cannot be done now with confidence. Models are used by all of us in the sciences today, and certainly definitive uses have been and will continue to be made of them. Our caution relates to their inappropriate use. If such modelling is used in control policy formulation at the present time, and, of course it is being used now, then the modeller should provide the user with realistic estimates of the magnitude of the uncertainty associated with the results so that these can be incorporated into the control strategy planning. Such a practice is not suggested to frustrate the control plan, but it is necessary to provide the sense of realism that is demanded in view of the very high costs involved in the contol of sulfur oxide emissions.

One final point should be made. The NRC report states that the Rodhe, Crutzen, Vanderpol model (1981) which was used to explain the possible nonlinearity between $SO_4^=$ deposition and SO_2 emissions should be modified in the light of recent specific laboratory findings (Stockwell and Calvert, 1983). Reviewer A doubts that this modification would significantly influence the result. It should be noted that the suggestion of the NRC report, supported by simulations of Professor Perry Samson of the University of Michigan which are given in the report, was tested independently in a comprehensive model of the gas phase chemistry of SO_2, NO_x and hydrocarbons by Hov (1983). It was found that complete regeneration of radicals in the SO_2 oxidation reactions as suggested by the laboratory study leads to a nearly proportionate (linear) response of reduced sulfuric acid formation to reduction in SO_2 emissions in long-range transport; 50% reduction in SO_2 gave a 48% reduction in sulfate generated.

Certainly the conclusions of the NRC committee on acid deposition are necessarily very limited in nature, and indeed they must and will be checked by extensive further experimentation. Our conclusions represent the best judgment of a group of highly qualified and diversified scientists, and we certainly would not alter or compromise these conclusions on the basis of the unusual "review" of the Manowitz group.

Jack G. Calvert
Alan Lazrus
Senior Scientists
National Center for Atmospheric Research
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Boulder, Colorado, 80307

Attached in the next seven pages of this report is a discussion presented by Professor James Williams of the Department of Statistics, Colorado State University related to the statistical problems in treating the Hubbard Brook data.

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Hov, 0. (1983), "Model Calculations of the Effect of SO_2, HO_x or HC Emissions Changes on Regional Scale Sulfate and Nitrate Production," p. 214-219 in Proceedings of the CEC Workshop Organized as Part of the Concerted Action "Physical Chemical Behavior of Atmospheric Pollutant", ed. S. Beilke and A. J. Elshout, D. Ridel Publishing Co.

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Stockwell, W. R., and J. G. Calvert, (1983), The Mechanism of the $HO\text{-}SO_2$ Reaction, Atmospheric Environment, in press.

Tanner, R. L., and B. P. Leaderer (1982), Seasonal Variations in the Composition of Ambient sulfur-containing aerosols in the New York Area, Atmospheric Environment, 16, 569-580.

Comments on the "Review" of Manowitz referee D by Professor James S. Williams, Department of Statistics, Colorado State University, Fort Collins

A. Linear and Nonlinear Systems; Linear and Nonlinear Regression

Members of the National Academy of Sciences study panel have focused on the question of whether or not emission-deposition processes for SO_2-SO_4 and NO_x-NO_3 are linear or nonlinear. Reviewer D contests the published conclusion by panel members that linearity is a workable approximation for those systems in North America that are like the one sample in the Hubbard Brook Experimental Forest in New Hampshire. The definition of linearity set out in the panel report (p. 73) appears to be the same one used by the reviewer in much of his analysis, discussion, and conclusions. However the definition is too restrictive, as noted (at least by implication) in both the report and review.

A linear system in real variables is one in which input variable $\underline{x}$ is transformed into $t(\underline{x})$ where the function $t(\cdot)$ is characterized by:

$$t(\underline{x} + \underline{y}) = t(\underline{x}) + t(\underline{y}) \text{ for all } \underline{x}, \underline{y} \in R^p$$

In such a system if input is changed from $\underline{x}$ to $m\underline{x}$, then output is changed from $t(\underline{x})$ to $mt(\underline{x})$. In particular if $\underline{x}$ is a numerical measure of man-made emissions and $t(\underline{x})$ is a measure of depositions, then reducing emissions to a fraction m of $\underline{x}$ would reduce depositions to the same fraction m of $t(\underline{x})$. If man made emissions were eliminated ($m = 0$), then depositions would be eliminated. This last result is unrealistic because undoubtedly there are depositions which are not the result of man-made emissions. This objection can be removed by considering other types of systems. Systems of the type just described are called homogeneous linear; a more appropriate type for consideration is nonhomogeneous linear systems for which:

$$t(\underline{x}) = t(\underline{0}) + u(\underline{x})$$

$$u(\underline{x} + \underline{y}) = u(\underline{x}) + u(\underline{y}) \text{ for all } \underline{x}, \underline{y} \in R^p$$

In such a system input results in a homogeneous linear charge added to output associated with zero input. If input is changed from $\underline{x}$ to $m\underline{x}$, then the output is changed from $t(\underline{x})$ to $t(\underline{x}) + mu(\underline{x})$. In such a model for an emission-deposition process, the elimination of man-made emissions ($m = 0$) would not eliminate depositions, but would reduce them to a natural level ($t(\underline{0})$). Also the rate of change in output with respect to any particular input variable can be a constant other than 1, the only value it can be if the system is homogeneous linear.

A system which is not linear is nonlinear. It is characterized by rates of change which are not constants but instead depend on $\underline{x}$. For such a system, the change in output in response to a change in input can be calculated but it is more complicated in form than the change in output for a linear system.

The terms linear and nonlinear are also used to qualify different types of regression analyses. However, they are not used in this context in the same way that they are used to characterize a transformation of input into output. For example, the nonlinear transformation of a single input variable $\underline{x}$ into output $t(\underline{x})$ which is given by:

$$t(\underline{x}) = \beta_0 + \beta_1\underline{x} + \beta_2(1/\underline{x})$$

might be used as the basis of the model of linear multiple regression analysis. With respect to the regression analysis, linear applies to the manner in which the coefficients β_0, β_1, and β_2 enter the equation for $t(\underline{x})$ rather than to the manner in which $\underline{x}$ enters the equation. In general, the methods of linear regression apply to all linear transformations of input $\underline{x}$ into output $t(\underline{x})$ and either exactly or approximately to a very large class of nonlinear transformations. There are also methods of nonlinear regression analysis which can be applied to nonlinear transformations to replace approximate procedures by exact ones and to enlarge the class of transformations of input to output that can be studied with a regression analysis.

The conclusion to be drawn from this discussion is that the conclusion presented by the panel members and contested by the reviewer is not as central as the former indicate and is not as restrictive to consideration of emissions control policy as claimed by the latter.

B. Statistical Analysis of Relationship of Deposition Data from Hubbard Brook Experimental Forest to Regional Emissions Data

Efforts to derive equations for the transformation of emission variables into deposition variables have not been successful enough to predict the latter in any given region from measurements of the former in nearby and more distant regions. One can predict with confidence that such equations will never be found because the system includes a number of random components which cannot be included in such equations. The successes of studies of this type will increase our knowledge of possible workings of tranport, chemical conversion, and deposition processes in the system.

Satisfactory predictions can be derived from the results of regression analysis if the more important variables affecting deposition can be identified and measured and if sufficient data can be collected to insure accurate results of a regression analysis. At the present time the complete list of important variables for even one deposition site, such as the Hubbard Brook Forest, is unknown, and only a modest amount of data are available for analysis. These two reservations are clearly stated in the panel report and are given as reasons for their basing conclusions on an informal analysis for qualitative descriptions of relationships. No attempts were made at formal analyses for quantitative descriptions and predictions.

The main difficulty one would encounter in a regression analysis of the relationship of the Hubbard Brook Forest data to the emissions data for the Mississippi valley and regions to the east can be seen in Figures 4.14 and 4.15 of the panel report. The modest trends present in the series of yearly deposition figures for $SO_4^=$, NO_3^-, H^+, and pH (Figure 4.14) are hypothesized to be responses to trends in the series of yearly emissions for five regions either nearby the Hubbard Brook Forest (Regions I and II) or more distant (Regions III, IV, and V). These emission trends contain strikingly different changes in direction for SO_2 and leveling out for NO_x. In each region there is a year of maximum SO_2 followed by a decline in levels. This occurs in 1965 for Regions II and V, in 1970 for Regions I and III, and in 1975 for Region V (Figure 4.15). The apparent decline in $SO_4^=$ deposit begins in 1968 (Figure 4.14). If it is a positive response to changes in emissions, then it must be a delayed effect of the turn downward in SO_2 emissions in Region II and/or Region V. If it is a negative response to changes in emissions, then it must be an indication of increasing dominance of Region IV on the level of SO_2 contamination reaching the Hubbard Brook Forest. In each region, the level of NO_x emissions either levels off or even declines slightly after a period of increase. This occurs in 1965 for Region III, in 1970 for Regions I, II, and V, and in 1975 for Region IV (Figure 4.15). The increase in NO_3^- deposition lasts until 1970 (Figure (4.14) and, therefore, is apparently a positive response to emission changes in Regions I, II, and V or a negative response to increasing dominance of Region IV on levels of NO_x contamination reaching the Hubbard Brook Forest. Also the possibility that effects on one source of acid deposition might be indirect, that is the consequence of changes in the other source, cannot be overlooked.

Summary indices of emissions from all sources, such as the totals for SO_2 and NO_x graphed in Figure 4.15 or the weighted totals for SO_2 and NO_x presented by Reviewer D, are inappropiate input variables unless they are constructed to emphasize by correct weighting, the real effects of the regions on the levels of contaminants in the air mass of the region where deposition is measured. Reviewer D has implied that weighting by either inverse distance or inverse squared distance is correct. However he presents no analysis to support this conclusion and his citation of the study published by Munn et al. is inadequate because the analyses prepared by that group are so few in number and unfocused.

An important point to realize is that the regression analysis cannot be used to identify sources of emissions which truly affect deposition variables in a region. However the analysis can be used to eliminate some of the regions which have negligible effects if the data record includes patterns in changes in emission trends which can be used to distinguish each region from all others. It is fairly certain that a long record would be needed to achieve this. It cannot be done with the available data because trends in Regions I, II, and III are similar for SO_2 and trends in Regions I, II, III, and V are similar for NO_x emissions (Figure 4.14).

Reviewer D has based his conclusion that yearly SO_4 depositions are not linearly related to SO_2 emissions on regression analyses in which an input index is used. An example of one of these indices is graphed in his Figure 2 along with a graph of adjusted SO_4 depositions in the Hubbard Brook Forest. The reason that there is no significant linear relationship is obviously due to the marked counter trends in the two series up to 1970. Were Region II to receive greater weighting in the index, much of the upward trend in the SO_2 trace would be eliminated, and a stronger positive linear relationship would be obtained. Were Region IV to recieve greater weighting in the index, much of the downward trend in the SO_2 trace would be eliminated, and a strong negative linear relationship would be obtained. It is clear that the decision of how to weight regional emissions in the index determines the sign and the statistical significance of linear dependence of SO_4 depositions on SO_2 emissions. Were the correct weightings known, the regression analysis could be properly applied to determine if there is evidence in the data for linear dependence. Panel members in their report have argued that the correct weightings are not known and that as a consequence a formal analysis is not justified (p. 140-141).

C. Statistical Adjustment of Deposition Data to Eliminate Effects of Meteorological Variables

Reviewer D has used linear regression procedures to adjust deposition measurements taken at Hubbard Brook Forest for precipitation volume, surface temperature (at Concord, New Hampshire) and all other factors associated with cosine variation in seasonal trends. It is not clear whether the analysis for coefficients used in the adjustment was calculated from the data broken into yearly subsets (a within-year analysis) or from the unpartitioned records because the reviewer notes that coefficients are the averages of several coefficients (page 8). Presumably this comment refers to something else because only the latter method of calculation is appropriate.

The choice of cosine variable to represent cyclic trends is ineffective because year-to-year variations in seasonal effects which are necessary for a proper adjustment are not included in the cosine variable. The only consequence of inclusion of the cosine term could have would be to increase the residual variance of the adjusted records and thereby reduce the statistical significance of tests based on the adjusted data.

Both panel members and the reviewer note that summer deposition of $SO_4^=$ dominates the yearly record. Because of this, further analyses of $SO_4^=$ data should be done separately for the yearly records of depositions during warm and during cool seasons. Changes in the yearly deposition trend should show up more clearly in the warm season record than in the yearly record.

APPENDIX B: THE ORIGINAL "MANOWITZ REVIEWS" OF THE NRC ACID DEPOSITION DOCUMENT[*]

[*] These "reviews" were subsequently rewritten in part and submitted to the Honorable Robert T. Stafford, Chairman of the Senate Committee on Environment and Public Works at the Senate hearing of his Committee held on November 2, 1983. The attached original "reviews" were circulated widely within the Power Industry and Federal and State Government circles; they were reviewed by Allan Lazrus and Jack G. Calvert of the NRC Committee. Since the science discussed here is the same as that in the "sanitized report" presented to the Senate Committee we have included here the original report to which our comments (Appendix A) refer. The various anonymous reviews which appear here can in large part be identified through the new document. These are as follows:

Reviewer A: Stephen E. Schwartz (Brookhaven)

Reviewer B: Lawrence I. Kleinman (Brookhaven)

Reviewer C: Paul Michael (Brookhaven)

Reviewer D: Fred Lipfert (Brookhaven)

Reviewer E: Not identified, but the highly edited version of this is attributed to W. G. N. Slinn, M. T. Dana, and R. C. Easter (Battelle Pacific Northwest)

Reviewer F: Largely due to Jack Shannon (Argonne)

The scientific questions raised in the reviews attached are essentially those in the revised "reviews" which were submitted to the Senate Committee on Environmental and Public Works by Bernard Manowitz of Brookhaven National Laboratories recently.

BROOKHAVEN NATIONAL LABORATORY
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July 26, 1983

Dr. Herbert Friedman, Chairman
Commission on Physical Sciences,
Mathematics and Resources
National Research Council
2101 Constitution Avenue, N.W.
Washington, DC 20418

Dear Dr. Friedman:

As Chairman of the National Laboratory Consortium of the Interagency Task Force on Acid Precipitation, I have been asked by two federal agencies and by a Congressional committee to solicit comments from the National Laboratories on the document recently issued by the National Academy Press entitled "Acid Deposition Atmospheric Processes in Eastern North America" under your aegis.

Since I understand that your Commission is meeting on August 1, 1983 and since the reviews I have received thus far disagree with the major findings of the Academy report, I am bringing a series of these reviews to your attention.

The major points made by the reviewers are these:

- The historical record of wet deposition at Hubbard Brook, NH, in relation to emissions trends in the Northeast, plays a major role in the arguments for "linearity" (and implied proportionality). Since Hubbard Brook is well outside the region of maximum emission and deposition, it is unlikely that experimental data could reveal whether processes are linear or not. (Reviewers C, D).

- There are strong arguments on theoretical grounds that non-linear atmospheric chemistry processes can and do occur. Such nonlinearities would result in a less than 1.1 proportionality between emission and deposition. (Reviewers A, B, E).

- The Academy report attempts to relate the deposition trends at Hubbard Brook to Northeastern emission trends in a very superficial way, without confidence limits on the findings. Detailed statistical reanalysis of Hubbard Brook data, using multiple regression analysis to account for meteorological variability over the period of record as well as emission estimates for every year, finds a substantially less than 1:1 proportionality with a high degree of confidence. (Reviewers D, E, F).

In view of the negative and substantive comments of a significant number of reviewers, all of whom are active in the field, I question the quality of the review given to the Academy report.

Sincerely,

Bernard Manowitz
Chairman - National Laboratory
Consortium of the Interagency Task
Force on Acid Precipitation

BM:mh
att. 6
cc: D. Beecy, Chairman, Task Group B
O. Bentley, Co-Chair, ITF
J. Calvert, Chairman, NRC Comm.
K. Demerjian, Chairman, Task Group C
R. Kasper, Exec. Dir., Comm. Phys. Sci., Math. & Resources
L. Machta, Co-Chair, ITF
C. Riordan, Co-Chair, ITF

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Department of Applied Science

July 26, 1983

Dr. Raphael G. Kasper
Executive Director
Commission on Physical Sciences,
 Mathematics and Resources
National Research Council
2101 Constitution Ave., N.W.
Washington, DC 20418

Dear Dr. Kasper:

I recently had a conversation with Dr. Herbert Friedman, Chairman of the Commission, regarding a number of negative comments I have received on the Academy's Acid Deposition Report. He asked that you make the attached letter and comments available for the Commission's August 1, 1983 meeting.

Sincerely,

Bernard Manowitz

Bernard Manowitz
Chairman, National Laboratory
 Consortium of the Interagency
 Task Force on Acid Precipitation

pt
att. 7

Reviewer A

Review of National Academy Report on Acid Deposition

This report focuses upon the relationships between emissions of acid precursors and the deposition of acidic substances. The stated purpose is "to assess the current state of scientific information that can be marshaled to describe those relationships in the hope that our assessment will be valuable to decision makers in the government and in the private sector" (pp. 1-2).

Overall, the report exhibits a number of positive qualities, but in my judgment it is seriously flawed. On the positive side, it delineates well the scientific issues that confront the regulatory sector. The red herring of natural sources is readily dispensed with (p. 3). The scientific issue is thus drawn as establishing the relationships between anthropogenic emissions and deposition. The report also defines the sub-issues of nonlinearity and distant vs. local sources. The report draws the conclusion that "evidence exists for long-range transport of pollutants leading to acid deposition", but cautions that "the relative contributions of specific source regions to specific receptor sites currently remain unknown" (p. 5). The report points out gaps in knowledge requisite to establishing such contributions and suggests pertinent laboratory, field, and modeling studies to better define such relationships. The report concludes that at the present level of understanding "we cannot objectively predict the consequences for deposition in ecologically sensitive areas of changing the spatial pattern of emissions in eastern North America, such as by reducing emissions in one area by a larger percentage than in other areas" (p. 11). In my judgment, the report makes an adequate case for the above conclusions. However, as I argue below, the report might well have offered some guidance, particularly with respect to the latter question.

On the negative side, I submit that the report is deficient insofar as it focuses, almost entirely, on long-term average (e.g., annual) deposition, to the exclusion of consideration of information that has been gained from shorter-term measurements. While such a focus may be appropriate from the perspective of ecological concerns and/or from a regulatory perspective, a wealth of detail is lost that is pertinent to the mechanism of acid deposition, and pertinent, therefore, to the stated subject of the report. The focus on long-term relationships between emissions and deposition leads to a number of conclusions that either are erroneous or subject to misinterpretation or, alternatively, are so narrowly drawn as to border upon the self-evident. I call particular attention to the following:

(a) "Pollutants are being thoroughly mixed over a region with linear dimensions up to 1000 km" (p. 9). This conclusion derives from the claimed near-constancy (in space and time) of the ratio of long-term average sulfate and nitrate concentrations in precipitation and the near equality of this ratio to the ratio of the oxides in emissions. The statement is patently incorrect if we take "thoroughly mixed" in the usual sense of "exhibiting uniform concentration over the volume in question, at a given instant or over a given period of time." Evidently, the authors mean simply to say that the ratio of long-term average atmospheric concentrations is uniform spatially. In any event, the statement as it stands is erroneous and certainly detrimental to conveying the authors' point.

(b) "There is no evidence for strong nonlinearity in the relationships between long-term average emissions and deposition" (p. 7). Presumably the authors mean to say here, "There is no evidence for strong nonlinearity in the relationships between long-term average emissions and long-term average deposition." Accepting that, the statement summarizes the search for such a relationship in available, long-term records of precipitation concentration. As it turns out, there is essentially only one station that meets the authors' criteria for such records of acceptable quality, and the authors claim to discern no such relationship for that station. While that may be argued (and I am sure it will be), restricting the discussion to long-term averages excludes a wealth of evidence from short-term measurements (event or sub-event) that is demonstrative of mechanistic nonlinearities, the understanding of which is crucial to the description of the source-receptor relationship in acid deposition.

(c) "If we assume that all other factors, including meteorology, remain unchanged, the annual average concentration of sulfate in precipitation at a given site should be reduced in proportion to a reduction in SO_2 and sulfate transported to that site from a source or region of sources" (p. 10). This statement is so highly restrictive as to be essentially useless. Strictly, it deals only with the relationship between annual average concentration of sulfate in precipitation at a given "site" and, presumably, annual average atmospheric SO_2 and sulfate at that "site," under the assumption that "all other factors, including meteorology, remain unchanged." Even granting the validity of the statement as it stands, the statement is all the more important for what it does not treat, i.e., (1) the relationship between emissions and annual average atmospheric concentrations at sites remote from emissions, and (2) the factors which are assumed to remain unchanged. While it might be hard to quarrel, on the basis of annual-average measurements, with the statement as it stands (although I can think of at least three mechanistic reasons why it might not be expected to hold in the short term and can cite, as well, any number of studies to that effect), I am concerned that the statement may be misconstrued as relating deposition to emissions, particularly insofar as it appears under the heading "Implications for Emission-Control Strategies," and immediately follows the statement that "analysis of observational data provides guidance for assessing the consequences of changing SO_2 emissions for wet deposition of sulfate."

(d) "Assuming that all other emissions and conditions remain unchanged, we would expect that if the molar ratio [of SO_2 to NO_x] in emissions in eastern North America were changed by changing SO_2 emissions, a similar change would occur in the ratio of sulfate to nitrate in wet deposition" (p. 10). The authors then go on to qualify the statement, indicating that "because the analysis is based on spatial distributions, its applicability is limited to circumstances in which the spatial distribution of emissions is not changed." Here, as above, I am concerned about possible miscontruction of the intent of the authors' statement. I am sure that some will see in this statement a policy implication that if sulfur oxide emissions are to be reduced, they should be reduced in such a way as to preserve the existing spatial distribution. On the other hand, I would foresee others who would take statement (a) above, that "pollutants are being thoroughly mixed over a region with linear dimension up to 1000 km," as suggesting that reduction in SO_2 emissions anywhere within the region will be equally effective in reducing annual average deposition of sulfate at all other points in the region. I submit that the proper strategy for emissions reduction to protect ecologically sensitive regions lies somewhere between these two extremes. Unfortunately, the report provides very little guidance to the policy makers who must formulate such a strategy.

In addition to the foregoing general comments, I have a number of comments relative to the linearity-nonlinearity issue. But first we must examine why linearity-nonlinearity is of interest at all. Clearly, if the geographical region is taken sufficiently large, then the long-term total deposition of SO_2 and $SO_4^{=}$ integrated over this area is linear in emission of SO_2 in this area, and for that matter equal. The question of nonlinearity in long-term deposition is therefore inherently a question of whether the scale of transport from source to receptor is influenced by the emission source strength. Clearly also, any negative departure from linearity in a given receptor region must be compensated by a positive departure from linearity in some other receptor region or regions. Thus, it is evident that the entire question of linearity-nonlinearity is deeply imbedded in the larger question of the scale of transport of the pollutants of concern. This point is not well brought out in the report. The failure to appreciate this point may be responsible for some of the confusion in the report over the question of nonlinearity.

Some specific comments on the treatment on nonlinearity follow.

(1) For all the care given to the definition of linearity (pp. 72-75), the report still seems to confuse linearity with proportionality. Thus, (p. 116): "The central question is whether the data [obtained from monitoring networks] can be used to judge whether deposition is linearly or nonlinearly related to emissions.... If the relationship is linear, a change in emissions would be reflected in a proportionate change in deposition; if it is nonlinear, the change in deposition, if any, would be disproportionate." The second statement above is at best loosely phrased and at worst flat out wrong. It could be corrected as follows: "If the relationship is linear, a change in emissions from a given source (or set of sources) would be reflected in a proportionate change in deposition due to that source (or set of sources)," and similarly for the second clause. The addition of the logical connection between the source and the receptor is, in my judgment, central to the entire question of acid deposition, and ultimately to the question of control strategy. However, setting that aside for the moment, it is disappointing to say the least to see propagation of such confusion in this forum.

Going beyond definitions, we see that the foregoing misconception is carried over into the discussion of the model runs by Samson (p. 76). Here, calculations are compared with and without the contribution of a "background" source. The report states that the shift from the solid to the dashed sets of curves depicted in Figures 3.1 and 3.2 is "the result of eliminating the trivial source of nonlinearity arising from the background source, term B in the equation, $c = kS + B$." This result is indeed trivial but it is not a nonlinearity and in any event is an observation that should hardly warrant discussion. The only reason that such a discussion can possibly have persisted into the final report is an inherent lack of understanding of the linearity-nonlinearity concept.

One further amusing (or saddening) point is the passing reference in the same paragraph to Figure 3.2 depicting "a result that is essentially linear (with proportionality constants less than unity)." The point of figures such as 3.1 and 3.2 is that any departure from the one-to-one line of percent Δ $SO_4^=$ concentration *vs.* percent Δ SO_2 (concentration or emission), sulfate concentrations from other, unchanged sources having first been subtracted out, is an inherent nonlinearity. In fact, the 24- and 48-hour graphs represent a departure from linearity of *ca.* 30%, potentially very important in the context of control strategies. This is not to argue that the model calculations are correct, but only that they are incorrectly interpreted.

(2) The report argues at some length (pp. 75-81) that model calculations of Rodhe et al. suggesting nonlinearity may be an artifact as a consequence of the incorporation in the model of a radical termination step involving SO_2, whereas the actual reaction may well be a chain propagation step: "The participation of reaction (3.1) results in a direct nonlinear feedback into the SO_2 oxidation mechanism, while reaction (3.2) does not seriously perturb the concentration of the hydroxy radical" (p. 78). This argument seems flawed by the following reasoning. We note (p. 80) that in the simulation studies of Calvert and Stockwell, only about 10% of HO-HO_2 radical termination occurs through the HO-NO_2 reaction, for the quite high NO_x concentration of 100 ppb (and less for lower NO_x; indeed, the report suggests a curious quadratic dependence). In any event, we note that the rate constant of the OH-NO_2 reaction is about tenfold that of the OH-SO_2 reaction, so that for 100 ppb SO_2, only 1% of radical termination would be due to SO_2 (again less for lower SO_2). Thus, the possiblity of any significant influence on radical concentration due to SO_2 termination reactions would appear to be ruled out.

(3) The discussion of nonlinearity in SO_2 deposition due to aqueous-phase processes (cloud, rain) is short (1.5 pages; pp. 81-82) and superficial. Reference is made essentially only to the H_2O_2 oxidation mechanism of SO_2 oxidation, focusing principally on the limiting reagent process. No discussion is given at all of the pH dependence of SO_2 solubility and aqueous reaction kinetics, which would be inherently nonlinear insofar as H_2SO_4 (and to a lesser extent SO_2 itself) would influence cloudwater pH. This process has been the subject of much research over the past decade (as summarized in Appendix A, pp. 178-193), but little of this research finds it way into the discussion in the text. Other types of processes leading to

nonlinearity (e.g., non-constant nucleation efficiency as a function of aerosol loading) are also not treated.

In summary, the relationship of the linearity-nonlinearity issue to the larger problem of scale of transport and control strategies does not appear to be adequately recognized. Moreover, the details of the discussion of nonlinearity are superficial and flawed, and little recognition is given of the importance of the fact that nonlinearities, as exhibited in short-term phenomena, can influence the source receptor relationship. For these reasons, little import should be given to the conclusion of a lack of evidence for nonlinearity in the relationship between long-term average emissions and deposition.

Reviewer B

Comments on "Acid Deposition - Atmospheric Processes in Eastern North America - A Review of Current Scientific Understanding," National Research Council.

Three major issues are considered and appear to serve as foci for the material reviewed in the report. As stated on pages 6-9, these issues are (1) "applicability of models to decisions on control strategies," (2) "nonlinearity" and, (3) "influences of local and distant sources."

I. Models:

The authors have applied a healthy degree of skepticism and insight in arriving at their conclusions regarding the usefulness of models. To paraphrase the report (pp 148-149) ..... a great deal of research is required before the acid deposition problem can be described with precision by models. It is fairly clear that in this statement the usefulness of models is judged relative to the needs of policy makers, not to the needs of research scientists. The use of models, even complicated ones, by the latter group, should be judged by different standards. Although models cannot be used to make a priori predictions of many of the important features of the acid deposition problem, they can be used to good advantage by the research community in designing experiments, interpreting data, performing controlled computer experiments on the environment and, in general, increasing our understanding of how the various pieces of a complex problem interact with each other.

II. Nonlinearity:

An unsupported conclusion is reached regarding the relation between emissions and deposition. "It is .... improbable that the oxidation of SO_2 is sufficiently hindered by a lack of oxidant to cause a disproportionately small reduction in sulfate concentrations as a result of a given reduction in SO_2 emissions." (p 9). The "evidence" in the text for this statement derives from a comparison of deposition at Hubbard Brook with emission, from consideration of the gas phase oxidation chemistry of SO_2 and from the sulfate to nitrate molar ratio in precipitation as compared with emissions. This evidence, some of which can be interpreted in different ways, as described below, does not support the stated conclusion that deposition is linearly related to emissions. At best, one could say, "Direct evidence of a strongly nonlinear relationship between wet deposition of sulfate and SO_2 emissions is limited to extensive historical data in Europe." (p 139). Specific comments on the "evidence" against nonlinearity follows:

- p 42, also p 84. "In theory, the amount of H_2O_2 formed in gas-phase reactions and taken up in cloud water and precipitation, is sufficient to oxidize a large fraction of S(IV)." Many photochemical calculations of the PBL predict a H_2O_2 concentration of a few tenths to approximately one ppb (Schiavone and Graedel, 1981; Rodhe, et al, 1981; Hov, 1983). In order to account for the composition of summertime precipitation in the northeastern U.S., several times this amount of oxidant and SO_2 is required. It is certainly possible that future calculations or experiments will show that $\left[H_2O_2\right]>\left[SO_2\right]$, perhaps as a result of an in-cloud or free tropospheric source of H_2O_2. It is misleading, however, to imply that a large enough oxidant supply has been identified.

- p 50. "The most important attachment process under most in-cloud conditions is undoubtedly nucleation." Judging from a following sentence, diffusional attachment (of gases and particles) appears to be a subset of "attachment."

Either there is a semantic difficulty or the role of gas phase SO_2 and HNO_3 in acidifying precipitation is seriously understated.

- p 80. The criticism of the nonlinearity produced in Rodhe's model is supported by many other experimental and theoretical studies (see, e.g., Miller, 1978; Hov and Isaksen, 1981). Although it appears likely that the gas phase oxidation of SO_2 is linear, there is no assurance that the aqueous phase oxidation is likewise linear. It is a deficiency of the main text (Chapters 1-5) that the relative amounts of gas and aqueous phase oxidation are not treated. Estimates of the relative importance of these processes have been made based upon the isotopic composition of precipitation (Holt, et al, 1981), the abundance of aerosol SO_4^{2-} (Newman, 1979; McNaughton and Scott, 1980), and a comparison of the acidity of precipitation and aerosol (Newman, 1979; Scott, 1982). At this point, the evidence, though largely inferential, points strongly to the in-cloud oxidation process as being the largest contributor of SO_4^{2-} to precipitation (Oppenheimer, 1983). The concern is that the aqueous pathway is the most significant and that it is nonlinear due to either pH inhibition or oxidant limitation.

- p 120-123. Comparison of Hubbard Brook data with emissions. It is misleading to base this comparison upon two years of monitoring and emissions data, namely 1965 and 1978. Emissions have a broad maximum around 1970 which is not reflected in precipitation composition. The two sets of curves, in fact, look sufficiently dissimilar such that one could argue that there is a complicated nonlinear relation between emissions and deposition.

- p 135. The NO_3^- to SO_4^{2-} ratios do not justify the conclusion that there is sufficient oxidant for all or most of the SO_2 within eastern North America. It admittedly is more straightforward to assume that equal deposition and emission ratios imply a high removal fraction for both substances than to arrive at an explanation for why the average removal fractions are both equal but substantially less than one. The proposed high removal efficiency of NO_x is based upon the rapid formation of HNO_3 and the high solubility of HNO_3. A high NO_x wet removal efficiency is, however, not in accord with summertime, air quality observations in moderately polluted areas which indicate

$$\frac{SO_4^{2-}}{SO_2} > \frac{HNO_3 + NO_3^-}{NO_x} .$$

Perhaps HNO_3 is rapidly removed by dry deposition thereby making it unavailable for wet deposition. A NO_3^- to SO_4^{2-} molar ratio in precipitation equal to emissions could then occur without requiring efficient scavenging of S compounds.

- p 137. The data in Table 4.9 reflects the different average heights of NO_x and SO_2 emission sources. In general, during the nighttime $NO_x > SO_2$. This occurs, in part, because low level NO_x emissions are trapped above the boundary layer.

III. Source Attribution:

The text contains a good description of the monitoring evidence to the effect that receptor areas are impacted from many source regions, sometimes simultaneously. The complexity of the source attribution problem is conveyed as are the hopes and shortcomings of several diagnostic methods. The notion of strong mixing is, however, considerably overstated due to the authors' reliance on long term (monthly) average monitoring data.

Holt, B.D., Cunningham, D.T., and Kumar, R. (1981). Oxygen isotopy of atmospheric sulfates. Environ. Sci. Tech. 15, 804-808.

Hov, O. (1983). One-dimensional vertical model for ozone and other gases in the atmospheric boundary layer. Atmos. Environ. 17, 535-549.

Hov, O. and Isaksen, I.S.A. (1981). Generation of secondary pollutants in a power plant plume: A model study. Atmos. Environ. 15, 2367-2376.

McNaughton, D.J. and Scott, B.C. (1980). Modeling evidence of in-cloud transformation of sulfur dioxide to sulfate. JAPCA 30, 272-273.

Miller, D.F. (1978). Precursor effects on SO_2 oxidation. Atmos. Environ. 12, 273-280.

Newman, L. (1979). General considerations on how rainwater must obtain sulfate, nitrate, and acid. Presented at the Division of Environmental Chemistry, The Am. Chem. Soc., Honolulu, Hawaii, April 1979.

Oppenheimer, M. (1983). The relationship of sulfur emissions to sulfate in precipitation. Atmos. Environ. 17, 451-460.

Rodhe, H.P., Crutzen, P. and Vanderpol, A. (1981). Formation of sulfuric and nitric acid in the atmosphere during long range transport. Tellus 33, 132-141.

Schiavone, J.A. and Graedel, T.E. (1981). 2-D studies of the kinetic photochemistry of the urban troposphere. I. Air stagnation conditions. Atmos. Environ. 15, 163-176.

Scott, B.C. (1982). Predictions of in-cloud conversion rates of SO_2 and SO_4 based on a simple chemical and dynamic model. Atmos. Environ. 16, 1735-1752.

7/25/83
Review C

The Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation of the National Academy of Sciences in their recent report state that "there is no evidence for a strong nonlinearity between long-term average emissions and deposition," (Summary page 7). They admit that the conclusion is clouded by uncertainty (p. 9) due to "the limited amount and uncertain quality of the data, the natural variability of atmospheric processes, and the lack of firm understanding of the physical and chemical processes involved." Beyond these disclaimers, there are a number of questions that can be raised concerning the basis for the NAS conclusions. These points need resolution before the conclusions are used for the setting of emission control policies.

1. ONLY WIDE-AREA, LONG-TERM CONCLUSIONS ARE DRAWN

The NAS committee looked at long-term data only; they did not address the short-term (event) or the spatial scale of less than a few hundred kilometers. The million-square kilometer so-called mixing that they discuss occurs only as an artifact of averaging over long time periods.

On the other hand, it is, no doubt, true that if a large enough area is considered, the acid deposition response to emissions will be linear. The real question is "On what scale is the system linear?"

2. THE USE OF HUBBARD BROOK DATA IS QUESTIONABLE

The deposition concentrations at Hubbard Brook are somewhat lower than those in the region of highest concentrations (by almost a factor of two).

The very nature of mechanisms that can cause nonlinearities (i.e., limited amounts of oxidant, competition among species, pH-induced limitations on mass transfer, etc.) means that, at first approximation, the effect will be most evident where the concentrations are the highest. However, because of the fact that the system will appear linear if averaged over a large enough region, an opposite effect is liable to be seen where lower concentrations occur far downwind of the high source and concentration regions. For example, a lack of sufficient oxidant in a region would allow unoxidized SO_2 to be vented from a storm and made available farther downwind. Hence, an increase (or decrease) in emissions might result in a smaller than proportional increase (or decrease) in concentrations near the region of high emissions; thus, a proportionally greater (or lesser) amount of unreacted primary pollutant will be available to be deposited downstream. Following this line of reasoning, it is quite possible that Hubbard Brook could be in a location where ambiquous results on linearity would be obtained. The attached figure illustrates the point.

3. INSUFFICIENT ATTENTION IS GIVEN TO IN-CLOUD CHEMICAL REACTIONS AS A POSSIBLE SOURCE OF NONLINEARITY.

There is a large amount of admittedly inferential evidence that a major portion of precipitation acidity derives from in-cloud oxidation. Quite a number of authors have put forth this point of view (Newman, 1979; Scott, 1982; Lazrus, et al, 1983; Oppenheimer, 1983; etc.). Hence, the effort to discredit the model of Rodhe, et al,(1981) might well be moot; the Rodhe treatment of in-cloud oxidation is quite simplified and does not seem to have been improved in the calculations reported in the NAS report. The report discusses how H_2O_2 production might be suppressed in a NO-rich polluted atmosphere and how it is unreacted SO_2. They recognize that this could be the source of nonlinearities, but note the lack of an adequate data base to test the possibility. The report states that the data "suggest that concentrations of (oxidant in cloud water) may be sufficient in eastern North America for complete oxidation of SO_2 except, perhaps, in winter." There are a number of photochemical calculations that would indicate that the H_2O_2 concentrations are several times too low. At best, the point is arguable; it might just be that the NAS report is incorrect.

4. "LACK OF EVIDENCE FOR STRONG NONLINEARITIES" IS NOT A PROOF OF LINEARITY.

Stating that "no evidence of strong linearity" could be found is far from being a logically sound proof of linearity.

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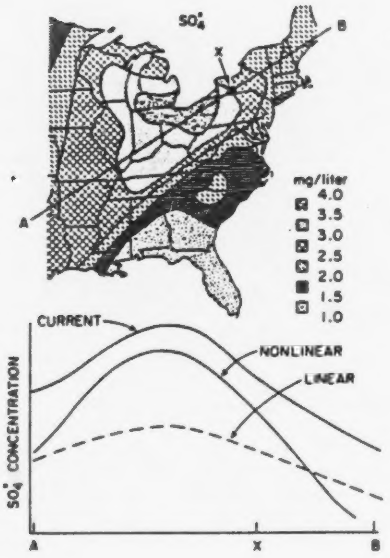
SO$_4^=$
B
X
A
mg/liter
4.0
3.5
3.0
2.5
2.0
1.5
1.0
CURRENT
NONLINEAR
LINEAR
SO$_4^=$ CONCENTRATION
A
X
B

Fig. 1. Top--Observed 1979 average concentration of $SO_4^=$ in precipitation (after Wilson and Mohnen, 1982). Bottom--Current concentration along cross section A-B and hypothetical concentrations that would result from an emission reduction if the response were linear or nonlinear.

Reviewer D

CRITIQUE OF CHAPTER 4 — EMPIRICAL OBSERVATIONS AND SOURCE-RECEPTOR RELATIONSHIPS

Introduction

Part of the thrust of the NAS report is that, given the present state of source-receptor modelling, we must rely on empirical observations to infer relationships between emissions and deposition and then to assess responses to mitigating strategies. One of the data sets presented for this purpose was the 16-year record of weekly wet deposition at the Hubbard Brook Experimental Forest in Central New Hampshire. While the emphasis on experimental observations may be appropriate at this time, the analysis presented was superficial and inappropriate to not only the Academy but to the importance and economics of the issue at hand.

The Hubbard Brook data have been extensively discussed and analyzed elsewhere.[1,2] But a serious attempt at a time series analysis relating these measurements to historical emissions of acid-forming precursors has not been presented, nor have quantitative relationships between wet deposition and air quality been assessed. Such a study is in progress and preliminary results are presented below.

The Academy Analysis (pp. 116-126)

The Academy analysis is based on a loose comparison of time trends between 1965-66 and 1979-80* for sulfate concentratons and emissions trends between 1965 and 1978 for any of several geographic regions. The emissions data are from the U.S. Canadian Work Group 3-B report,[3] which also reports data for two intermediate years, 1970 and 1975 (unfortunately, 1975 is a recession year and does not provide a reliable basis for trends between 1970 and 1978). Concentrations of nitrate in rain vis-a-vis NO_x emissions are also discussed, but more briefly. No statistical relationships are attempted between rain chemistry and emissions, nor are any confidence limits given for possible associations.

The trend in sulfate concentration (but not nitrate) is deduced from a linear regression analysis on 15 annual volume-weighted means, presumably giving each year equal weight. No explanation is given for excluding the two end periods, 1964-65 and 1979-80 (including them reduces the slope by about 10%). However, the trend in emissions over an equivalent period is deduced from only the two end points of the series, 1965 and 1978. The detailed behavior over the included time period is totally ignored as if the trend were monotonic (and linear) between these end points. Figure 4.15 shows that is decidedly not the case, even using the unrepresentatively low year of 1975 as a valid trend point. The fact is that 1970 (or thereabouts) is generally the peak year for SO_x emissions, after which the impact of the Clean Air Act of 1970 began to be felt. However, these reductions were realized slowly, so that the years 1968-1974 are practically flat for national SO_2 emissions. The decrease began sooner in the Northeast, about 1972. In contrast, Figure 4.14 shows an increase in $SO_4^=$ concentrations during this period. To be fair, however, it should be mentioned that a linear regression of the individual weekly samples shows an overall drop of about 20% over 15 years (discussed more extensively below).

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*Hubbard Brook publications use a "water-year," beginning in June.

In addition to using disparate analytical methods for the concentration trends vs the emissions trends, the Academy report does not deal with the question of estimating which geographic regions' emissions have the most direct impact at Hubbard Brook. By implication, the analysis points towards the nearby locations (Federal Regions I and II) and would totally exonerate Region IV, where emissions increased 33% from 1965 to 1978.

A similar process is followed for nitrate vis-a-vis NO_x emissions. Including the two end periods in a linear regression on time increases the change from +8% to +23% (increase with time). The emissions increase, calculated from only the two end points 1965 and 1978, was 8.6% for Federal Regions I and II, whereas the NO_x emissions increase for Regions I-V was 27%. Thus, the implication as to whether NO_x has an influence from areas further away than New Jersey is critically dependent on which measurement years are used at Hubbard Brook. Using all the data to determine the trend would imply that more distant source regions should be considered for NO_x (but not for SO_2), an argument that runs contrary to the discussion on sulfate/nitrate ratios in the Academy report.

The Academy report concludes, with regard to the Hubbard Brook data, that there is "no evidence for a strongly nonlinear relationship between annual depositions and annual emissions in the Northeast." As a result, elsewhere in the report, the finding is reached that a reduction in emissions would result in a proportional reduction in deposition. This implies a 1:1 relationship or an elasticity of 1.0 [a 1% change in emissions would yield a 1% change in deposition (or concentration)]. It should be clear from the data in the Academy report that this finding is not supported, even with the limited analysis presented.

For sulfate concentrations, the following elasticities result from the Academy analysis, depending on the region of SO_2 emissions to be controlled:

Region I	1.15
Regions I and II	1.18
Regions I and II and III	0.67
Regions I - V	0.25

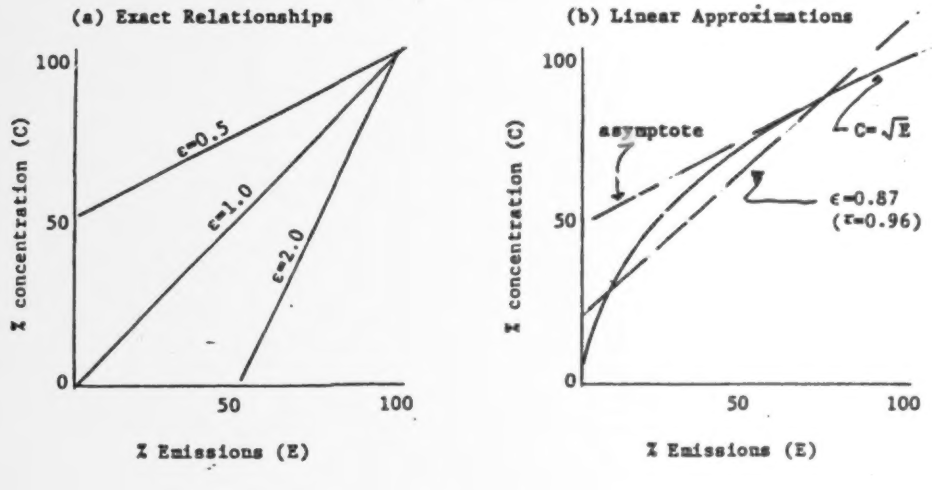
Thus, given the uncertainties of the analysis, the linear (i.e., proportional) hypothesis is supported if only the emissions from Regions I and II are considered for control, but not if Regions further south and west are included. The bulk of the report (and most of the extant literature on source-receptor relationships) makes it clear that such more distant regions should in fact be considered.

To illustrate the relationship between elasticities (as deduced from linear regressions) and hypothetical non-linear relationships, consider Figure 1:

Figure 1(a) shows three linear relationships with differing elasticities. The proportional relationship, $\epsilon = 1.0$, yields a 50% reduction in concentration (or deposition) for a 50% change in economics. However, if $\epsilon = 0.5$, only half the benefit is realized due to the presence of a y-intercept which could represent deposition arising from natural background or from sources outside the region of consideration. Converse arguments hold for $\epsilon = 2.0$.

Figure 1(b) shows how an actual non-linear relationship ($C = \sqrt{E}$) might be represented by linear approximation, for example derived from regression analysis. A linear regression through the entire curve (11 points spaced every 10% in emissions) yields a correlation coefficient of about 0.96, explaining 92% of the variance (which would be considered an excellent fit). The slope (and hence elasticity of this line is 0.87, which is not very different from unity. Yet if reductions in emissions are postulated of the order of 50%, the asymptotic linear approximation shows that only about half of the expected benefit would be realized in fact. It should be noted that in most cases, we are working with the upper ends of the curves in question (the range in National SO_x emissions from 1965 to 1979 is about 5 million tons out of a total of about 30 million.

It should be clear from this example that it is extremely unlikely that statistical analysis of time trends will be able to detect nonlinearities per se. However, differences in the elasticities of linear best-fit relationships should indicate the degree of proportionality to be expected. The range of elasticities given above, based on the figures in the Academy report, indicate that no conclusions on linearity or proportionality can be made from this analysis.



(a) Exact Relationships

(b) Linear Approximations

Figure 1

Reanalysis of the Hubbard Brook Precipitation Chemistry Data (1964-79)

Because of the importance of this data set, a reanalysis of the weekly (bulk) samples has been carried out, using multiple linear regression methods. The dependent variables were the amounts of precipitation in each weekly sample and concentrations (μeq/ℓ) of the following ions: H^+, $SO_4^=$, NO_3^-, Cl^-, Al^{+++}, NH_4^+, Ca^{++}, Mg^{++}, K^+, SiO_2, $PO_4^≡$ and Na^+. Concentrations were corrected for sea salt content assuming that all the sodium is derived from that source. Further, the balance between positive and negative ions was calculated, and only the observations for which this balance was achieved within ±20% were retained (about 87% of the observations or about 440 values).

The following independent meteorological variables were used:

PRECIP — the amount of each weekly sample
WAVE — a periodic function intended to be a surrogate for such seasonal effects as photoperiod, wind trajectory variations, fraction of convective vs continuous storm, etc.

$$\mathrm{WAVE} = \cos\left[\left(\frac{\text{day of year}}{365} \times 360\right) - 180 \ast \frac{\pi}{180}\right]$$

MAVTEMP — monthly average surface temperature at Concord, NH (finer time resolution not readily available).

The influence of trajectory differences by year at Hubbard Brook was considered in detail by Munn et al.[2] SO_4 concentrations were normalized by accounting for the frequency of occurrence of 5 different wind direction sectors; concentrations tended to be higher for trajectories originating to the south and west of Hubbard Brook than from the east, for example. However, this normalization had only a trivial effect on the actual annual median SO_4 concentrations, increasing the overall mean about 1-3%, but with virtually no change in the standard deviation from year-to-year. Thus, by implication, the differences shown from year-to-year in median sulfate concentration are not due to trajectory variations. The assumption that this source of variation may be ignored in a multiple regression analysis without creating bias appears to be well-founded.

The emissions data were computed for each year from 1964 to 1979 based primarily on fuel use data[4] at the state level for the United States. Statewide fuel sulfur contents were derived from FPC Form 67 data from 1969 to 1976. For years prior to 1969, these values were assumed constant. For years after 1976, emissions by state were estimated from published EPA reports. In general, this approach captures only combustion-derived emissions, a limitation that is not believed to be serious for the Eastern United States. Canadian copper-nickel smelter emissions[5] were also included for those years, as was an estimate of other eastern Canadian emissions,[6] for which only 2 years' data were available requiring linear interpolation to represent the 16 year period.

Quarterly shares of emissions were available for 2 years (1965 and 1978),[9] for the SURE region (Northeastern U.S.). The differences between these shares and a uniform annual distribution were minor, with higher emissions in the winter. When used, these quarterly shares were applied to all emissions estimates, regardless of geographic region. A conservative estimate of the number of degrees of freedom for the emissions data is then 18 (16 annual values plus 2 quarterly shares). Comparison of these independent emissions estimates with those of EPA shows somewhat higher estimates but similar trends (for the years available from EPA).

As an alternative to aggregation by summation, weighting schemes were considered in order to combine emissions from the various geographic regions thought to have an influence at Hubbard Brook. Both inverse linear and inverse squared weightings were used, based on distances from Hubbard Brook to the estimated emissions centroids of the regions.

Multiple linear regressions were performed, using the stepwise mode and the meteorological variables listed above together with various emissions variables. The regression step selected for detailed consideration was either the one with the lowest standard error of estimate (highest adjusted R^2) or the subsequent step upon which the emissions variables entered the regression. Examination of residuals did not indicate autocorrelation to be significant, based on the Durbin-Watson statistic.

It was hypothesized that sulfate deposition at Hubbard Brook derived from two separate sources: aerosol which had been scavenged by precipitation, and sulfate formed in clouds. The aerosol portion was proportional to the concentration of ammonium ion (NH_4^+) in precipitation. Thus, the balance ($SO_{4eq}^{=}$ - NH_{4eq}^{+}) would be a surrogate for the sulfate formed in clouds. An alternative estimate of in-cloud sulfate subtracted the calcium equivalent in addition ($SO_{4eq}^{=}$ - NH_{4eq}^{+} - Ca_{eq}^{++}), recognizing that calcium is an important ion at Hubbard Brook, with a substantial downward time trend. However, since calcium is thought to be derived from suspended dust of coarser particle size that ammonium (sulfate), these two ions were not summed to represent aerosol derived from anthropogenic emission sources.

Table 1
Elasticities and 95% Compliance Limits

Relationship	Emissions Region	Summed Emissions	Linear Weighting	Squared Weighting
NO_3^- vs NO_x	State of NH	0.75±0.36	—	—
	Region I	0.25±0.45	—	—
	Regions I - II	0.70±0.85	0.89±0.62	0.70±0.51
	Regions I - III	1.41±0.58	1.17±0.69	0.84±0.56
	Eastern North America	1.12±0.61	1.03±0.57	0.88±0.51
	All U.S. + E. Canada		0.88±0.47	0.84±0.47
$SO_4^=$ vs SO_2	State of NH	0.05±0.30	—	—
	Region I	−0.27±0.44	—	—
	Regions I - II	−0.59±0.62		
	Regions I - III	−0.42±0.84		
	Eastern North America	−0.22±0.88		
	All U.S. + E. Canada		0.59±0.71	±0.42±0.46
NH_4^+ vs SO_2	State of NH	0.60±0.52	—	—
	Region I	0.47±0.35	—	—
	Regions I - II	0.55±0.43	0.53±0.40	0.51±0.38
	Regions I - III	1.01±0.68	0.81±0.56	0.63±0.46
	Eastern North America	1.00±0.67	0.96±0.65	0.81±0.57
	All U.S. + E. Canada		1.94±1.19	1.18±0.77
$(SO_4^= - NH_4^+)$ vs SO_2	State of NH	−0.11±0.33	—	—
	Region I	−0.49±0.48	—	—
	Regions I - II	−0.91±0.68	0.11±0.26	0.10±0.24
	Regions I - III	−0.93±0.92	0.15±0.36	0.12±0.29
	Eastern North America	−0.73±0.96	0.21±0.42	0.17±0.37
	All U.S. + E. Canada		0.20±0.77	0.20±0.50

Table 1 presents preliminary results from this analysis, based on the following:

- Only data for which an ion balance was achieved within ±20% were retained.
- Annual rather than quarterly emissions were used (elasticities are slightly lower and less statistically significant when the quarterly values are used).
- 95% confidence limits are based on 15 degrees of freedom (t = 2.13).
- Emissions are aggregated by Federal region in three different ways: summation, weighting by the inverse distance from Hubbard Brook to the estimated centroid of emission, and weighting by the square of that distance.

Nitrate Ion

Statistically significant relationships were shown for almost all cases. In most cases, the elasticities are not significantly different from unity. There is no reliable indication as to which emission region provides the best fit, but there does seem to be a tendency towards an area larger than Federal Regions I and II.

Sulfaction

There are no statistically significant relationships between sulfate in rain at Hubbard Brook and SO_2 emissions for any of the regions considered. However, the weighted "all U.S. + Canada" cases nearly achieved significance with an elasticity around 0.5 (most likely value).

Ammonium Ion

Ammonium ion (taken here as a surrogate for sulfate derived from aerosol) shows statistically significant relationships with SO_2 emissions in all cases. Moreover, as the region increases in size, the elasticity increases, indicating the need to control over a wide region for maximum effectiveness. However, as with nitrate ion, it is not possible to indicate the optimum region for control with any degree of confidence.

Sulfate Less Ammonium

The difference between sulfate and ammonium equivalents is interpreted here as a surrogate for sulfate formed in clouds. No positive statistically significant relationships are seen. Since it is difficult to conceive of a physically meaningful negative relationship, the weighted results appear to be the most credible and indicate no relationship between the two variables. This could indicate a situation of saturation, in which no more sulfate is formed if fresh SO_2 is supplied, and no less if SO_2 is reduced. Such a situation can only pertain locally, due to global mass balance considerations. Subtracting calcium in addition to ammonium ion did not materially change these results.

Figures 2 to 5 present plots of "seasonally adjusted" annual mean concentrations vs emissions. The "seasonal adjustment" procedure accounts for the effects of precipitation amount, monthly average temperature, and the seasonal periodic function (WAVE) by subtracting these effects as predicted by the regression equation, according to the following formula:

$$C_{seas.adj.} = C_{measured} - (K_1 * PRECIP + K_2 * WAVE + K_3 * MAVTEMP)$$

where the K's are given by the averages of coefficients for several regression equations.

Figure 2 presents the time trends for sulfate in precipitation at Hubbard Brook and for the linearly (inverse) weighted SO_2 emission parameter, which includes all of the U.S. and Eastern Canada. After 1970, the trends are reasonably concordant, but before 1970 they are opposing. The $SO_4^=$ plot looks much like Fig. 4.14 in the Academy report, even though weighting by precipitation volume has not been done in Figs. 2-5.

Figure 3 presents the cross plot, which indicates a weak (non-significant) positive relationship between the two parameters, with an elasticity of 0.35. An elasticity 1.0 line is also shown for comparison, and the two years used in the Academy report (1965 and 1978) are flagged. Note the very different impression created by considering just these two years.

Figure 4 presents a similar plot for ammonium ion, but in sharp contrast the data fit an elasticity $\cong$ 1.0 line with a highly significant correlation ($P < 1\%$). Figure 5 presents nitrate data vs the linearly weighted (inverse) NO_x emissions parameter, which also results in a highly significant correlation, but a lower elasticity than obtained with the weekly sample analysis. The use of only 1965 and 1978 would provide a reasonable estimate in this case.

Conclusion

This analysis has indicated that at Hubbard Brook, proportional reduction might be expected in nitrate and ammonium deposition from the control of NO_x and SO_2 emissions, respectively. Considerably smaller benefits if any, would be expected for deposition of sulfate ion.

Figure 2. Time Trends for SO_2 Emissions and Precipitation Sulfate

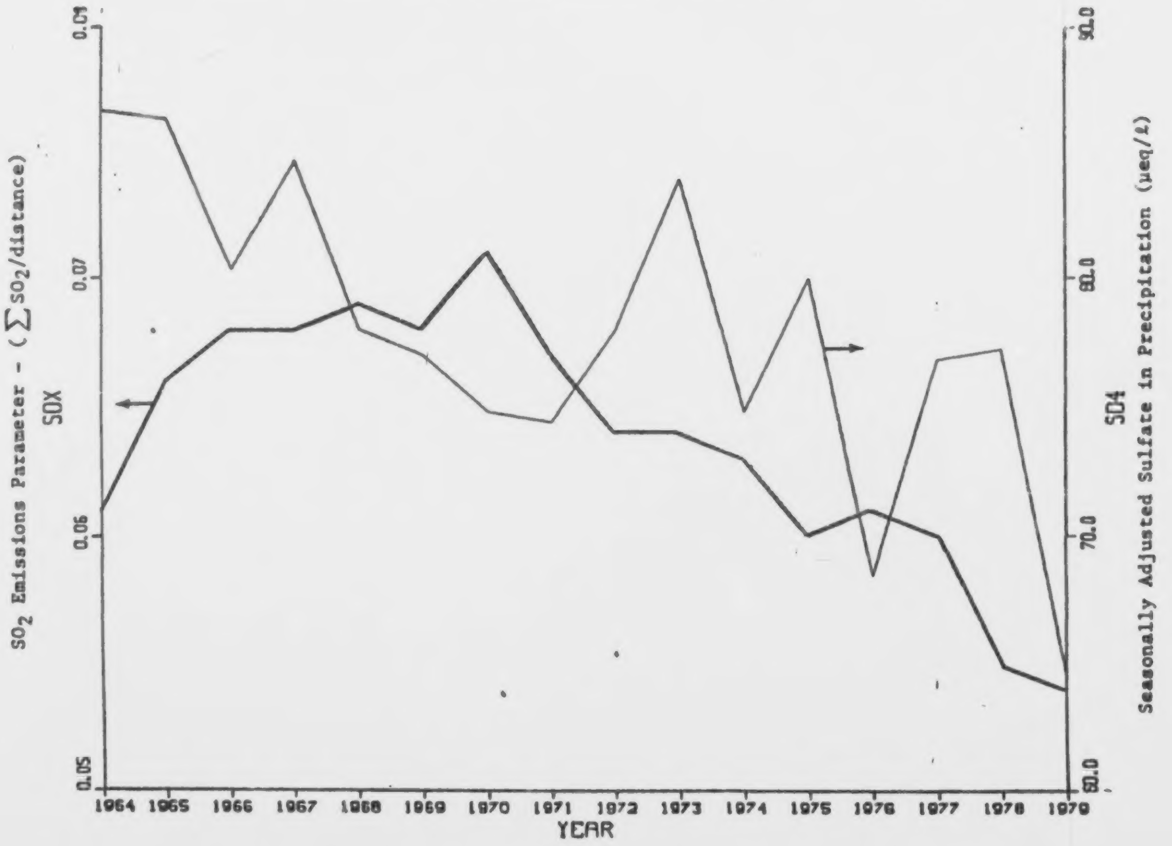


Figure 3. $SO_4^=$ vs SO_2 Emissions
(annual means)

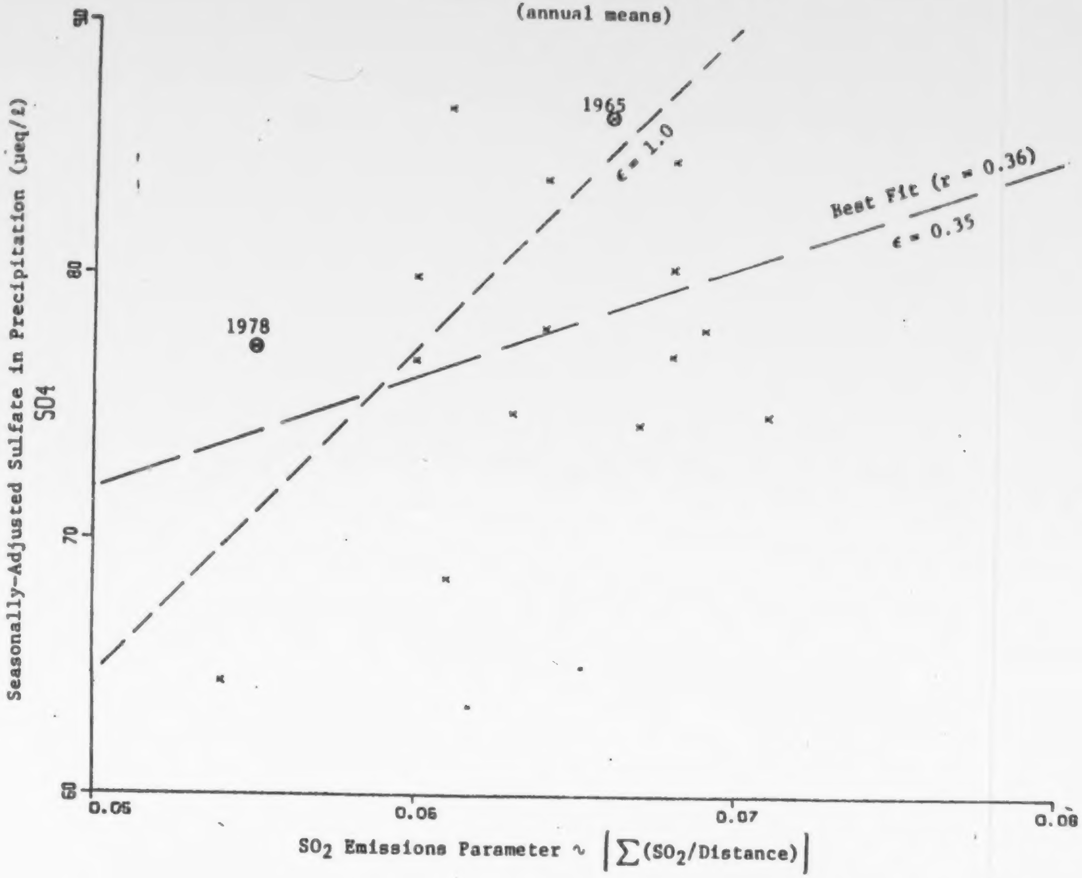


Figure 4. NH_4^+ vs SO_2 Emissions
(annual means)

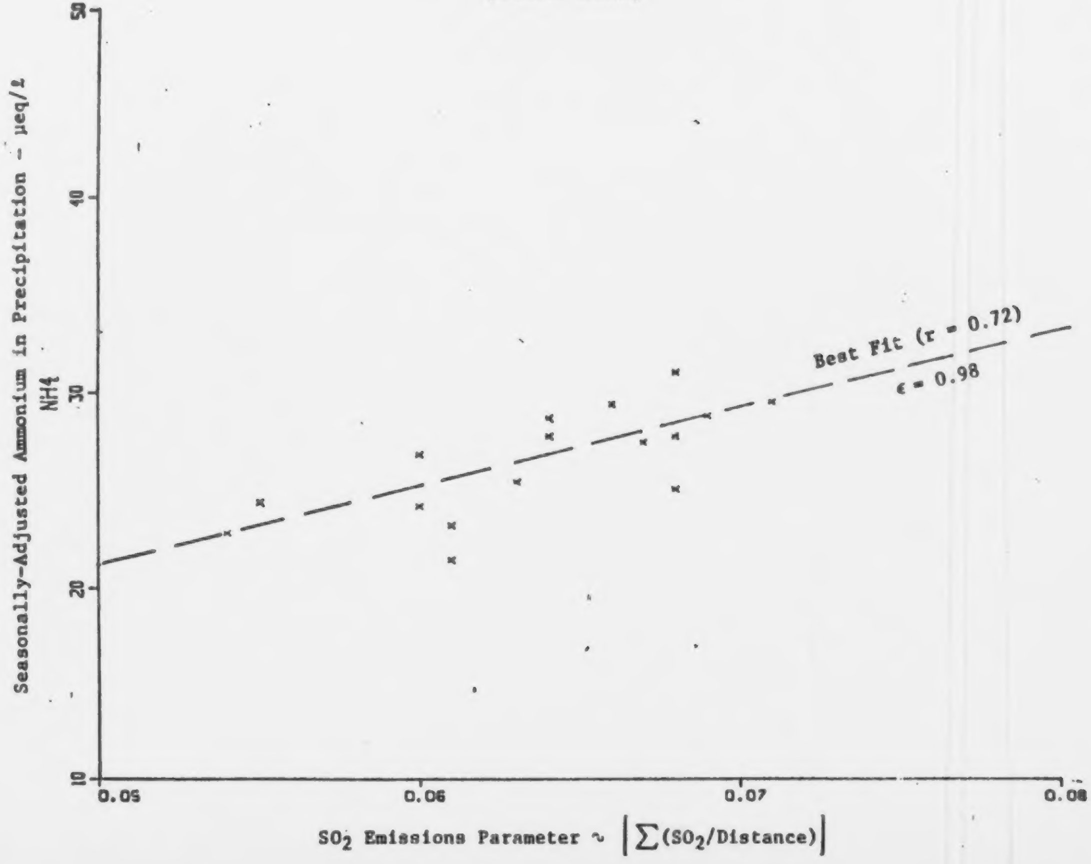
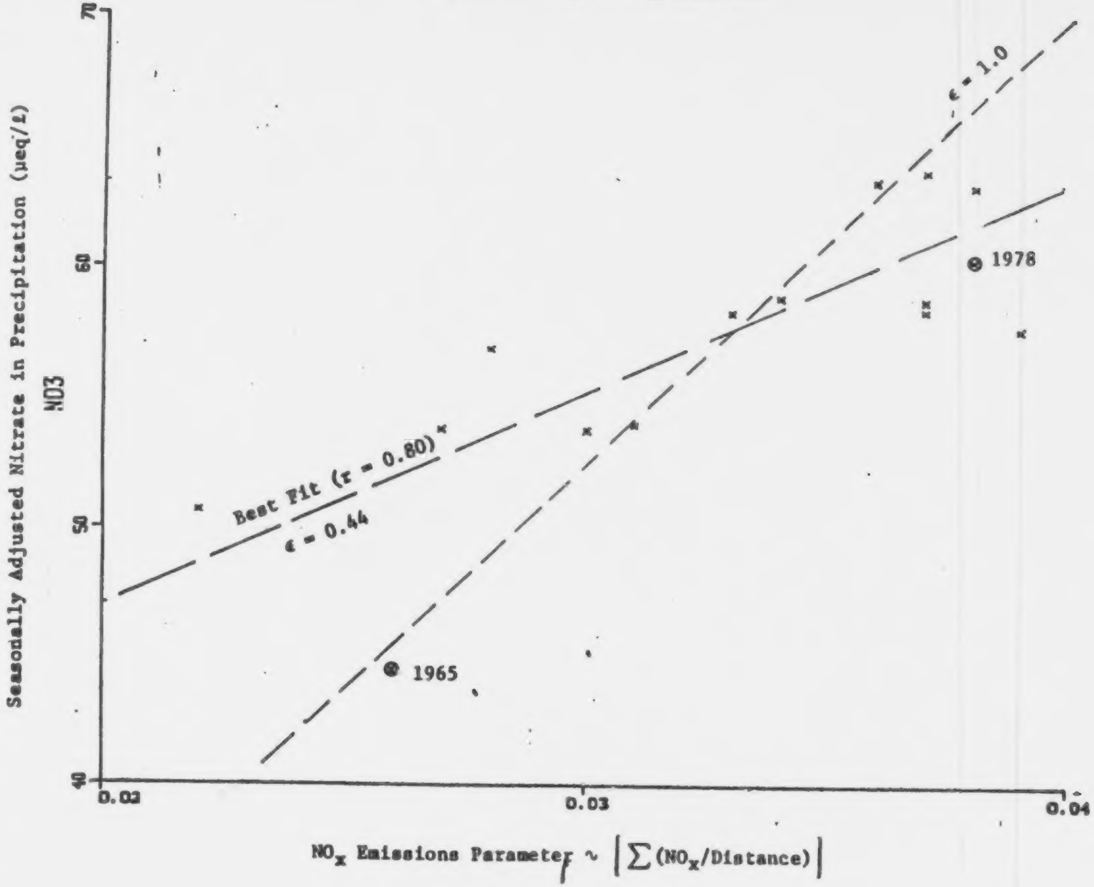


Figure 5. NO_3^- vs NO_x Emissions



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2. R.E. Munn et al., "A Climatological Analysis of the Hubbard Brook (NH) Precipitation Chemistry Data," Final Report to the U.S. Department of Energy, University of Toronto, Nov. 30, 1982.

3. Work Group 3B (Emissions, Costs, and Engineering Assessment), U.S.-Canada Memorandum of Intent on Transboundary Air Pollution, Final Report, June 1982.

4. U.S. Department of Energy, Energy Information Administration, Federal Energy Data System Statistical Summary Update, DOE/EIA-0192, July 1979.

5. Air Pollution Control Directorate, Environment Canada, EPS3-AP-80-5, January 1981.

6. Frank Vena, personal communication, Sept. 28, 1982.

Reviewer E

Review of the report by the National Research Council (Environmental Studies Board of the Commission on Physical Sciences, Mathematics, and Resources)

"ACID DEPOSITION -- ATMOSPHERIC PROCESSES IN EASTERN NORTH AMERICA -- A Review of Current Scientific Understanding",

which was prepared by the Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation, with membership: J. Calvert (Chairman), J.N. Galloway, J.M. Hales, G.M. Hidy, J. Jacobson, A. Lazrus, J. Miller, and V. Mohnen.

<This review was written (during a rushed, 40-hour weekend) by Reviewer E , who has published approximately 50 open-literature papers in the fields of precipitation scavenging and dry deposition during his past 16 years of research in these fields>

INTRODUCTION TO THIS REVIEW

This report published by the NRC is very strange. If one were to start reading at Chapter 1 (rather than first read the cover letter by F. Press and the Summary), then the first half of the book (and the associated appendices) flow along quite well. Oh, there are small problems, but nothing too serious. Thus, on p.24, L9, the goals of the project are clearly stated:

"If this goal <reducing the hydrogen ion deposition in sensitive regions by 50 percent> were adopted, by how much would emissions have to be reduced? Conversely, by how much would deposition rates be reduced if there were specific reduction in emission rates?", and on p.24, middle:

"Our objective was to determine what conclusions can be drawn from the state of knowledge late in 1982 about the relationships between emissions and deposition."

Some small problems encountered include the weak description on pp. 30-35 of transport and mixing (even when Appendix B is added), the tendency to jump on the "H_2O_2 oxidation bandwagon" (what a lot of red faces there will be -- or should be -- if HNO_3 is found to be the dominant aqueous-phase oxidizer of SO_2), weak descriptions of wet and dry deposition (but well compensated by Appendix C), and an error in describing the influence of gradients of diffusion at the bottom of p.50 (see later).

But then things start going more poorly in Chapter 3. After first reading the description of models (pp. 55-72), I looked again to see who were the authors. As expected from the poor description of the models, I found that not one of the authors is a long-range transport modeler: the committee was overwelmingly dominated by chemists and chemical engineers.

Then, halfway through the book, the excrement definitely becomes entangled with the impeller. On p. 69, middle, we gain the first hint that the Committee does not plan just to review current work that is available to the scientific community, but instead plans to plow into a few virgin fields by themselves. "It is almost certainly true that the scheme of Rodhe et al. fails to do this (include the essential chemistry) properly."

That's all it says. No reference. As yet, no alternative. Just: Rodhe et al. are wrong. <I'll come back to this point later, but let me at least mention the essence here. It seems that the chairman of the Committee has recently coauthored a paper -- accepted for publication but not yet available for study by the scientific community -- that purports to have a better homogeneous gas-phase oxidation scheme for SO2 than the one-used by Rodhe et al. Yes, gas phase; yes, gas-phase oxidation of SO2 may be ignorable; yes, the Chairman!>.

And then, on p.72, it happens. They stumble into it this way (3rd paragraph):

"Recently, in connection with proposals for mitigating acid deposition, the question has arisen as to whether deposition rates are linear functions of emissions."

Here we are, halfway through the book (or farther, if account is taken of the appendices), and this is the first time the linearity/nonlinearty issue arises. THE COMMITTEE THEN BECOMES ENGROSSED IN THIS ISSUE FOR THE REST OF THE BOOK, ROYALLY SCREWS IT UP, PRESENTS UNSCIENTIFIC, SUBJECTIVE, HAND-WAVING, ATROCIOUS "ARGUMENTS", ABANDONS ANY LINK WITH CURRENT SCIENTIFIC OPINION, AND DISREGARDS THE STATED OBJECTIVES OF THEIR STUDY. And it is this linear/nonlinear issue that is picked up by Press and the press.

Worst, as chemists, they focus on chemical nonlinearity (e.g., not first-order reactions) and thereby, almost totally disregard the heart of the nonlinearity issue (I say "almost", because this idea can be found in odd sentences in the text, but not in the summaries). The heart of the nonlinear issue is not whether the reactions are linear in concentrations, but whether there are any reactants available to react. That is, at heart, the question is: what is the spatial dependence of the deposition? This the Committee ignores, confining their attention in the rest of the book to large-scale spatial averages. The second-half of the book flows steadily downhill, save for the well-done chapter on research needs (if the reader can tolerate the Committee's use of the English language -- I could not).

In view of the disasterous second half of the book and in view of the emphasis on the second half that is contained in Press's cover letter and in the summary, I propose here to start this review at the beginning of the book (with the Cover Letter and the Summary), but give references to where in the text the summary material is coming from. Then, if I have time left during this working weekend, I'll try to type out my review of the text. My apologies to readers (if there are any) for typing, spelling, and grammatical errors. I do not have the time to review this production, and my Apple and I are just becoming acquainted (and words seem to be spelled and arranged differently on this screen from their appearance on paper!).

THE REVIEW

I. Title Page (p. i):

1. It should be "Acidic Deposition", not "Acid Deposition"

2. It will be seen that there is very little in this report on "Atmospheric Processes"; the authors are overwhelmingly chemists, not meteorologists.

3. And it will be seen that this should not be called a "Review of Current Scientific Understanding". A more appropriate subtitie would be: "Some Wild Speculations about Meteorological Processes by Chemists".

4. I am not impressed by the list of "responsible" groups (Committee..., Board...., Commission........Council); in reality, the speculations in this book are the responsibility of eight people, mostly chemists.

II. NOTICE (p. ii):

1. L.6: "The members of the committee <sic> responsible for the report were chosen <by whom?> for their special competence <in what?> and with regard for appropriate balance." <of what?> Stating something doesn't make it so. There is an overwhelming number of chemists on the committee, none of the Committee members has experience in modeling long-range transport and deposition of air pollution, and there are no representatives of the industries that would be influenced by the wild speculations that appear in this report.

2. L.9: "This report has been reviewed by a group other than the authors".
I would hope so! -- and I also would have hoped that the other group would have been more knowledgeable and less imbalanced by chemists, but apparently that was not the case.

3. L.23: "The Council has become the principal operating agency ... in the conduct of their services to the government, the public, and the scientific and engineering communities."
Most service will be provided by sticking to science. As scientists, we certainly must engage in wild speculations (also known as hypotheses). But these speculations/hypotheses are then to be tested, not published under a title of "A Review of Current Scientific Understanding."

III. Cover letter by F. Press, Chairman of the National Research Council (p.iii):

1. P1: "acid" vs. "acidic"

2. P2, S2: "The public policy implications of this relationship <of linearity vs. nonlinearity> are of major economic and political significance."
That is true, and it is therefore even more important that wild speculations be avoided -- but they are not.

3. P3, S2: "The Committee concludes that there is no evidence that the relationship between emissions and deposition in northeastern North America is substantially non-linear when averaged over a period of a year and over dimensions of the order of a million square kilometers."
I will return to this conclusion. Here, I only want to state

that the Committee also gives no evidence that the relationship is linear. Moreover, overwhelmed by chemists, the Committee doesn't seem to understand even the meaning of "linear" vs. "nonlinear". The Committee does, however, give evidence (but chooses to ignore it) that the system is saturated. Therefore

4. S3: "The Commitee's judgement that if the emissions of sulfur dioxide from all sources in this region were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition" does not conform with the evidence that the Committee gives, but chooses to ignore.

5. p.iv, P1 (if it is a paragraph! -- it lists the "several pieces of evidence", mentioned on the previous page), S1: "One is the well documented observation that the molar ratios of sulfates to nitrates deposited at many observation points in this region are nearly constant, and are similar to the molar ratios of the integrated emissions."

Of course I will respond to this point again, but even now, I would ask the reader to turn to Figs. 4.17 and 4.18 (pp. 130 & 131). This is the "well documented observation" that is being referenced. Look first at Fig. 4.18, showing the molar ratios of the emissions. I defy anyone to try to supply contours of constant ratios on this figure -- it looks like the results from a random number generator. Now look at Fig. 4.17 (and it would have been nice if the Committee would have included the data for Newfoundland). But look what the Committee did add: contours! A pattern! Giving what? Increasing sulfate to nitrate, farther from the source. What does this suggest? That the system is saturated! Moreover, EVEN IF THE MOLAR RATIOS WERE CONSTANT (BUT THEY'RE NOT!) THEN THE SYSTEM COULD BE SATURATED: if there is enough oxidant available to oxidized only a fraction of either NOx or SO2, then we don't KNOW if NOx would be preferentially oxidized IN PRECIPITATING SYSTEMS. In other words, this "well documented observation" doesn't suggest what the Committee says it does (in reality, the molar ratios show a definite trend, increasing farther from the source), and even if the ratio were a constant, that doesn't mean that the system is linear -- it would only mean that the ratio is constant, which could be explained in many ways.

6. S2: "The Committee believes <sic> that the simplest and most direct interpretation of this observation is the one they have given."

I agree: the Committee's interpretation certainly is simple minded. And I think that the word "belief" is highly appropriate. "Lief" is latin for wish; "belief", therefore, means "wish to be". In science, however, we must dispense with "liefing": - when a scientist starts "wishing" for something to be (other than a belief in objectivity), then science becomes dogma. Who cares what reality is; let's just describe it, objectively.

7. S3: "A second observation that supports the Committee's judgment comes form a 13-year run of observations at a single location in North America that shows the linear relationship between deposition at this one site and overall emissions."....and the price of rice in China.

Would the reader now please turn to Fig. 4.19, p.134. The data points scattered there (S4) "represent the result of well designed and carefully taken measurements" -- from a bucket left open for a full week, exposed to local dirt, leaves, bugs, bird droppings, near a power plant that was shut down in 1970 (note the decrease in sulfate in 1970), and near a highway on which traffic decreased in the early 70's (decreasing nitrates, and therfore increasing the ratios). No, I don't know if that is true -- but there is nothing in the report to justify the statement "well designed and carefully taken measurements", and again and again the authors of the report state that they can't evaluate the contributions from distant vs. local sources. In other words, the Committee repeatedly states that they can't trust single-point measurements, but here we are told that these single-point data form one of the "several" (three!) "pieces of evidence" on which their "judgement is based."

And what, I hope the reader will ask, are the other curves in Fig. 4.19? These curves are supposed to represent the molar ratios of emissions in the various EPA Regions (Regions I and II include New England and New York). Guilt by association? But I think that, in reality, the curves represent the confidence in the National Academy expressed by five scientists: steadily decreasing with time. How dare the National Academies put up a set of curves, give no scientific (hypothesis/test) basis for a correlation, yet suggest a correlation, and also suggest that this is "in the conduct of their services to the government, the public, and the scientific and engineering communities." Thank you, but if this is science, I withdraw my membership in the scientific community.

8. End P1: "Finally, the judgment draws upon the results of recent laboratory studies that are discussed in the report." Now of course it's difficult to pin them down on where they are "discussed in the report", but it appears that the major studies are those mentioned in the "Findings and Conclusions" on pp. 83 - 84 (top paragraph on p. 84: "On the basis of laboratory evidence, we conclude... Laboratory evidence suggests ..."). In turn, these studies are described on p. 78 - 79, where three points are blatantly apparent: (i) The referenced paper is not yet published and therefore has not been evaluated by the scientific community (which typically takes from 5 to 50 years), (ii) The referenced paper deals with homogeneous, gas-phase chemistry (and therefore is likely almost irrelevant to the issue of acidic rain), and (iii) The paper happens to be coauthored by the Chairman of the Committee.

And those three sum to give the evidence from which billion-dollar decisions are to be made? Joy!

9. P2, S1: "The Academies' process of selecting a diversified, expert study Committee and subjecting the Commitee's report to a substantive review was carefully followed in the preparation of this document."
Has anyone tested the process to see if it works?
10. P3, S1: "I believe..." Yes, I can understand that.

IV. Preface by J. Calvert, Chairman of the Committee,
bottom of p.ix, top p.x: It is important, I think, to take note of what was asked of the Committee (for later comparison with what the Committee produced). "... the Chairman of the NRC asked the Environmental Studies Board to review the current state of knowledge about atmospheric processes that link emissions to deposition" -- this was not done; the review of knowledge about long-range transport and models (e.g., Appendix B) is woefully inadequate -- "with the purpose of describing to the extent possible the consequences of the goal of reduced deposition for emissions." <sic -- whatever those words mean!> "By how much would emissions have to be reduced to reduce the deposition of hydrogen ions by 50 percent in sensitive areas? Conversely, by how much would depositions be reduced if there were specific reductions is emissions?"

And how great it would have been if the Committee could have seen behind the veneer and had the courage to describe what they saw. Oh, they have tried to help; but this way, in the long run, they do more damage than good. Can you imagine their saying: "Look, people, let's be realistic. Our society chose to release these huge quantities of SO2 and NOx to the atmosphere, and decided not to examine the consequences. Thereby, many of our scientific colleagues are unemployed, or driving taxis, selling real estate, farming, etc. These are honorable jobs, of course, but the parents of these scientists worked to realize their hopes, and the students worked very hard to learn science. If they had known that there was no employment in science, they would have skipped the effort, and gone directly from high school to these jobs, or trained for other jobs. And now, Mr. and Ms. Public and your representatives, you come to us and ask what to do about the pollution. Well, we're sorry, but we don't know. You never funded us to find out. Sure we could have told you, and we can yet, if you are prepared to fund us. But no, we're not going to engage in wild speculations about what to do about the pollution. That way we weaken science. If we did supply you with some wild ideas, any scientist worth the name will stand up and say: "That's bunk!'. What then? We would have weakened science. And in the long run, Mr. and Ms. Public, that will hurt you more than the pollution will."

V. Summary

1. p.2, last line: What is/are observational data? Is there some other kind?

2. p.3, L.9: "A long-term record (18 years)" <I thought Press said 13 years> "of reasonably reliable data" <How reliable is "reasonably reliable"? Press said "they represent the result of well designed and carefully taken measurements">.

3. p.3, end of P.2: "Currently the molar concentrations of nitrate and sulfate in precipitation are roughly comparable over much of the eastern United States." How rough is "roughly comparable"? Why did Press say "northeastern North America" and here it says "eastern United States"?

4. Para at bottom of p.3 top of p.4:
Here's a little game. Take the following three ingredients
(i) "Concentrations of sulfate in both the air and precipitation tend to reach their maximum values in summer in the northeastern United States"
(ii) 'Nitrate in precipitation shows much less seasonal variation in the northeastern United States"
(iii) "Currently the molar concentrations of nitrate and sulfate in precipitation are roughly comparable over much of the eastern United States".
The game is to determine how those three statements can be consistent. <The answer: bury it all in the word "roughly"! It's a great game. It can be played on and on: all concentrations are "roughly" at backgound levels; the system is "roughly" linear; "roughly", none of the pollution stresses the ecosystem;... Joy!>

5. p. 5, L9: What, pray tell, do the authors mean by "empirical analyses". My Webster gives me two options for the word empirical: (i) relying or based solely on experiment and observation rather than theory, or (ii) relying or based on practical experience without reference to scientific principles. If the authors are using "empirical" in the second sense, then I presume that the analyses are based on when the squirrels store their nuts, as recorded in the Farmer's Almanac. If the authors are using "empirical" in the first sense, then how can the adjective empirical be used to modify the noun analyses; it's like saying "nontheoretical theory". In either case it's sensible nonsense.

6. p.5, end of top Para: "But the relative contributions of specific source regions to specific receptor sites currently remains unknown."
What is meant by "unknown"? Is it known to within a factor of 2? Factor of 10? If it's known to within 27 decimal places, it can still be said to be unknown! The quoted statement is totally useless -- except as garbage words to fill up the page, as with "observational data" and "empirical analyses". I know these relative contributions to within a factor or 5, with 95 percent confidence; so how is it that the authors find that the "relative contributions ... currently remain unknown"?

7. Suppose I just ignore the "theoretical calculations". Maybe it is the case here, as with most chemists, that any calculation they perform is to be treated as an experiment -- with uncertain outcome!

8. But I can't let pass (p.5, P2, S3): "The methods employed to date, however, do not produce reliable estimates of spatial and temporal distributions of acidity..." Isn't that a beautiful scientific statement? Isn't it great to belong to such a profession?

"Doc, tell me, what's the chance that this operation is gonna kill me."

"Well based on observational data and empirical analyses, the answer is currently unknown."

"Ya sure Doc, but am I gonna live."

"Well, the methods employed to date do not produce reliable estimates."

"Gimme a number!"

"The actual limitations of predictive models ... are not well defined because of deficiencies in knowledge..."

"See ya around Doc."

9. p.6, L18: "However, current models have not provided results that enable us to have confidence in their ability .."
And statements such as that don't engender much confidence in the scientific abilities of the writers. How much "confidence"? What are the confidence limits? In the next paragraph: "Workers in the field generally have only limited confidence in current results." -- Be specific! A few more wishy-washy statements like that and this whole report will turn into slop.

10. p.7, middle para: Where did the laboratory studies all of a sudden come in? Why the comment about gas-phase reactions? WHo decided that gas-phase oxidatation of SO2 was so important as to be included here, under "ISSUES"? The chairman?

11. p.7, bottom: I've already commented some on this nonlinearity issue, and I'll return to it again. For now, I'll let it pass.

12. p.8, L7: "The only available direct evidence of strong nonlinearity between average emissions and average deposition of sulfur compounds is found in the extensive data taken in Europe over the past 25 years."
Why the word "only"? Or if only is to be used, how about only using it to describe the data as the only useful data available? In my opinion, the only scientifically satisfactory statement that the committee could now make is: "This is the only extensive data base available anywhere in the world, and though hypotheses can be made that there would be differences in North America, until data are available that test these hypotheses, we can only call the reader's attention to the European result."

13. p.8, middle: "These data (from the Hubbard Brook site) show no evidence of strong nonlinearity."
This is the kind of statement that makes me sick. The authors are scientists? WHAT, PRAY TELL, WAS YOUR STATISTICAL TEST? (And for those who can't stomach reading this whole book, let me tell you the answer: NO TEST! They drew 5 or 6 lines on a graph paper and said: "Hey look, they're all goin' the same way. Gee, there mustn't be any nonlinearity here." -- The lines? Does it matter? I think one was the height of women's hem lines, another was....)

14. p.8, 15 lines from the bottom. And now the report states "eastern North America", not just the U.S. What's it gonna be?

15. p.8, 3 lines from the bottom: "It is therefore improbable..." Please spare us from your weasel words. A few more "improbables" and "little confidence" and "advise caution" and I'm gonna get mad.

16. p.9, L3: Oh beautiful. Isn't that dandy: "The North American data therefore suggest ...." One plot that shows that the molar ratio DOES increase with distance (that's opposite from what the Committee says), and one time series from a single bucket, collecting local bugs -- these are THE North American data!? How about "from just two of the hundreds of sets of data that we could have examined, and from these two sets to which we have applied no objective, statistical tests, but instead, have used subjective eyeballing, learned in kindergarden, we guess that: 'Aw shucks, why not go ahead and spend the $100 billion and see what happens'."

17. p.9, middle: more of this "cannot be reliably estimated.." How I long for just one quantitative statement in this report.

18. p.9, second to last para: "Trends ... appear to reflect..." Joy!

19. p.9, 4L from bottom: "atmospheric processes ... lead to thorough mixing .. making it difficult to distinguish between effects of distant and local sources."

Isn't the information content in this report staggering?! Dear Editor: I have reviewed this report as you requested, and recommend that you through it in the trash.

20. p.10, top: Follow this logic if you can:

(i) "The implications of our findings and conclusions ... are limited." <Don't worry about what we're gonna say; the implications aren't important>

(ii) "It is <not> practical ... to rely on currently available models.." <So we won't do that>

(iii) "Data povides guidance" <So of course we're gonna use the data>

(iv) "If we assume ...."

HELLO. DO I SMELL A MODEL?

(v) "The annual average concentration of sulfate in precipitation at a given site should be reduced in proportion to a reduction in SO2 and sulfate transported to that site form a source or region of sources."

PRAY TELL WHAT DATA PROVIDED THIS GUIDANCE?

Oh, yes but of course, what's a few hundred billion more or less.. the "implications are limited"!

21. p.10, P3: But undaunted, this fountain of wisdom keep flowing: "It can be stated as a rule of thumb that the farther a source is from a given receptor site, the smaller its influence on that site will be per unit mass emitted."

Thank you. I wonder if we could survive without these chemists -- I sure as hell would like to give it a try.

22. p.10, next sentence. "Analysis of air-mass trajectories and modeling may provide insight..." Would someone please put a muzzle on these guys! "Interpretation of this information, however, is subjective .." If so, I nominate these chemists -- subjectivity seems to be their rule of thumb, and they're all thumbs.

23. p.10. The last paragraph is a gem. They give a totally

unsubstaniated, subjective opinion, and then state that they can't rely on models and therefore "cannot objectively predict the consequences ..." Don't get hung up on objectivity now, fellas; the lack of objectivity hasn't seemed to bother you up to now in this report.

24. p.11. S2 in last para: "It appears to us, however that useful information ... can be determined more quickly by direct empirical observation in the field.."

Beautiful!

"Observations", I understand.

"Direct observations", yes.

"Direct observations in the field"? How does one perform indirect observations in the field? Or direct observations of meteorological processes in a laboratory?

"Empirical observations"? Empirical in the sense of "relying or based on practical experience without reference to scientific principles"? What a strange recommendation coming from the National Academy of Science.

"Direct empirical observations"? What are INDIRECT empirical observations? If direct vs indirect, is there then some scientific principle? But that's not empiricism. Or do they use "empirical" in the sense of "relying or based solely on experiment and observation rather than theory"? Then what is an empirical observation? And why neglect the other half of science. Yes, SCIENCE. Oh, you people don't know about science? Hmmm. Yes, then, perhaps its best. Why don't you chemists just continue on with your "direct empirical observations in the field" -- far better you do that then engage in more of your wild speculations.

VI. Introduction

1. p.14, 7L from bottom: back to the "long-term (18-year) record of reasonably reliable data"

2. p.24, end of top para. The goals are stated clearly: "If this goal (reduce hydrogen ion deposition by about 50 percent) were adopted, by how much would emissions have to be reduced? Conversely, by how much would deposition rates be reduced if there weere specific reductions in emission rates?"

It's a pity that, when this draft (now, the final draft) of the report was finished, the authors didn't review their report to see that they didn't meet, or even come near meeting, these goals.

And they could have. For example, suppose they were to focus on deposition in the Hubbard Brook area. Available models of transport, diffusion, transformation, and deposition could predict the weekly-average deposition of sulfate and nitrate from sources within about 100 km, within known confidence limits. I expect that sensitivity analyses would show that the predictions were within a factor of two of reality. Then, available long-range transport models could precict the Hubbard Brooks' deposition from all sources, and the result could be compared with the data. I expect that sensitivity analysis would show that the comparisions with data were within a defined range of uncertainties of all parameters. Then, a different set of predictions could have been made and compared with an independent data set (e.g., at the MAP3S sites). After these exercises, I expect that the stated goals could have been satisfied for any region, with known confidence limits in the results (rather than the "wishy-washy" comments that permeate this report).

VII. Atmospheric Processes

1. pp.30-35: weak description of transport and mixing, and Appendix B is really quite poor.

2. p.42: bandwagon H2O2 oxidation? But let it pass. Appendix A is well done.

3. pp.44-53: in general, a weak description of the deposition processes, but acceptable in view of Appendix C.

4. p.50, 4L from bottom: No! "The motion of a molecule or particle ... by diffusion" does NOT depend on the gradient in concentration.

VIII. Theoretical Models

1. pp.55-68: This is really pathetic. Rather than all those words, how about showing some results?

2. p.70: "Dry deposition of NO2 differs somewhat from that of SO2 and is sometimes taken to be as little as on half that of SO2." I should hope so! How about two orders of magnitude smaller?

3. p.71, end: "Considering the crudeness ... it is suprising that the linear models perform better in estimatiing the long-term average wet deposition of sulfate than in estimating the ambient concentration."

What linear models? WHAT REFERENCE?!!

4. p.72, last paragraph, and continuing on to the end of this section, on p.75.

HOLD EVERYTHING. STOP. NOW WAIT A MINUTE. YOU GUYS HAVE MISSED THE POINT. THAT'S NOT THE LINEARITY VS. NONLINEARITY ISSUE!!!!!!!!!!!!!!!!

What are you guys, chemists by any chance? Familiar with reactions in test tubes, I presume. Oh yes, reactions can be linear or nonlinear in the concentrations. But suppose one of the reactants isn't present. Suppose you wanted to oxidize SO_2 but there is no oxidant. Whether the reaction is linear or nonlinear (your meaning) in the oxidant is beside the point: the reaction ain't gonna occur if there ain't no oxidant! That's why the term "saturated" is used: the system can be said to be saturated with SO_2. And in the atmospheric case, the system can then be nonlinear -- but it's not nonlinear in concentrations, it's then nonlinear in space. The system may be linear in the concentrations, but if there's nothing there to react, the system will respond nonlinearly: reduce emissions in the U.S. and the deposition in Greenland will be the first to start to decrease. Continue, and eventually there would be a response in Canada and then in the U.S. It's not a well-mixed test tube! (And of course I don't know if this will occur. But you don't know either -- so say so.)

5. pp. 75-82: And away you go with your focus on homogeneous, gas-phase chemistry. By any chance did the chairman write this section? There's a hint on p.78: "The best available experimental evidence today ... (Stockwell and Calvert 1983)!

And then did someone on the Committee do his best to rein him in? Page 82, complete with its uneven typing, leaves me with the distinct impression that somebody (Volker?), upon reading what was written, tried to holler "Chemists, whoa!":

"Note that for the case of an oxidant-limited reaction, a nonlinear response in sulfuric acid deposition WILL RESULT <emphasis added> from emission reduction....

"Limitations of oxidant for HSO_3^- or SO_2 BECAUSE OF PHYSICAL PROCESSES <emphasis added> as well as the chemical influences described....

"Several types of nonlinear effects may be expected from factors NOT IMMEDIATELY RELATED TO OXIDANT LEVELS <emphasis added>....

"...we judge that nonlinear effects....probably small FOR THE GAS-PHASE CONVERSION STEPS <emphasis added>...

And then, after saying: "However, these conditions cannot be tested from the existing data base", why not make one additional, obvious statement? Something similar to: "Therefore, we really don't have the foggiest idea whether the system is linear or nonlinear (saturated or not)."

Instead, there's this (p.82, 3L from bottom): "Significant nonlinearity is anticipated for certain special conditions..."

LIKE DURING RAIN, PERHAPS?!

Findings and Conclusions.
6. p.83, end of second para: Here's another case of incredible logic. Follow this.
(i) "However, because of .... we do not regard currently available models as sufficiently developed to be used with confidence in predicting responses of the atmospheric system to alternative control strategies."
(ii) Those models have taken very competent people decades to develop.
(iii) But we have a few weeks here, so we'll develop a model of our own, and tell the nation how to control emissions. (YES, THEIRS IS A MODEL; NO DATA SUPPORT THEIR CLAIMS.)
7. p.84, top: What's this about the Rodhe et al. model being "widely used."? Who else is using it?
8. p.85, middle. A KEY COMMENT. "Measurements of oxidant concentrations in cloud water, although limited, suggest that concentrations mav be sufficient in eastern North America for complete oxidation of SO2, except in winter."
JUST SLIPPED IT IN! NEVER MENTIONED BEFORE. NO REFERENCES. TOTALLY UNSUBSTANTIATED! BUNK!! WHO HAS MADE A SINGLE, RELIABLE, MEASUREMENT OF H2O2 IN CLOUD WATER? WHY IS AL LAZRUS NOW TRYING SO HARD TO PERFECT HIS METHOD? WHO SLIPPED THIS SENTENCE IN???
9. p.84, next sentence: "If this is the case, then strong deviations form linearity in the relationship between changes in annual average ambient SO2 concentrations and changes in the net production of sulfate in clouds would not be expected."
Oh? And why now "annual averages". And what about the fact that typically 50 percent of the deposition occurs during about 15 percent of the storms? And what about winter-time deposition? And what about the acidity from HNO3?

AND WHY? WHY ARE YOU GUYS DOING THIS? DO YOU THINK THAT YOU HELP THE PUBLIC BY DESTROYING WHAT LITTLE CONFIDENCE THEY MIGHT STILL HAVE IN THE INTEGRITY OF SCIENTISTS? WHY NOT STICK TO WHAT IS KNOWN? DON'T YOU THINK THAT YOUR COLLEAGUES ARE GONNA HOLLER "BUNK". THEY MUST, FOR AS MUCH AS THAT WILL HURT SCIENCE, NOT HOLLERING BUNK WILL HURT SCIENCE EVEN MORE.

IX. Emperical Observations (Gasp!) and Source-Receptor Relationships

NOTE TO THE READER: My 40-hour weekend is now drawing to a close; I must move more rapidly, and then tomorrow, get back to working on what I'm paid to do.

1. There isn't much on pp. 89-99, anyway.
2. p. 99, bottom: "A correlation analysis of sulfate particle concentration in dry air between various SURE sites indicates that significant regions of correlation generally extend 200 to 300 km from major sources and rarely beyond 500 km (EPRI 1981). The exception to this observation occurs during ducting of pollutatnts from southern regions to the Northeast by southwesterly air."
That could be an interesting result, but it isn't: the correlation is undefined (What phase lags were examined? How was this related to meteorology?), and the exceptional case is almost the only case of interest -- leading to acidic rain!
3. p.102, L6: Where did the Committee get the result: "In eastern North America, the warmer months tend to be the period of greatest precipitation ..." A grey-literature reference that happens to be sitting on my desk says: "The toal precipitation collected at the three MAP3S sites (during 1977 to 1979) had a winter/summer ratio of 1.06."
4. And more on p. 102, second to last sentence in this same paragraph: "These cases (European data) demonstrate that gas-phase photochemistry may not be the dominating factor contolling the seasonal trend of wet deposition of sulfate." What a strange way to put it? There wouldn't happen to be an advocate of gas-phase photochemisty on the Committee, would there?
5. And after all that statistics, it's neatly summarized on p.113, end of section: "However, empirical orthogonal-function analysis <they love that word empirical> and other statistical techniques have not progressed to the stage at which they can be used to predict consequences of slective changes in emissions.
6. And so too with tracers (pp. 113-116). Therefore, left with no science, the Committee boldly extends itself into the realm of hand-waving arguments!

SO HERE IT COMES, PEOPLE: 116 PAGES INTO THE REPORT, ALL SCIENCE HAS NOW BEEN DISMISSED, AND IN THE NEXT 138 - 116 = 22 PAGES, YOU WILL SEE (IF YOU'RE CAREFUL) HOW SCIENTISTS, CHOSEN BY THE NATIONAL ACADEMY OF SCIENCE, MAKE 100 BILLION-DOLLAR DECISIONS!

7. p.116, 16L from bottom: "The central question is whether the data can be used to judge whether deposition is linearly or nonlinearly related to emissions.
NO FELLAS, GO BACK AND LOOK AT YOUR CHARTER; THAT WASN'T THE CENTRAL QUESTION. MOREOVER, IT WOULD BE GREAT IF YOU GUYS KNEW WHAT WAS MEANT BY LINEAR VS. NONLINEAR, IN THE CONTEXT OF SATURATION.
8. p.117, L12: what a dandy way to put it. I commented on this before. Watch the location of the word "only" in this sentence:

"The body of European data provides the only direct evidence for this phenomenon." <of nonlinearity> Never mind that the European data is the ONLY data worth a damn.
9. p. 117, bottom: and so what does the Committee plan to use? The Hubbard Brook data. BULK SAMPLES (That means that the sampler is open all the time, to provide a toilet for the birds, a swimming pool for bugs, a collector for leaves,....), COLLECTED ON A WEEKLY BASIS (why not: if Mother Nature didn't like weeks, then why did she invent weekends?), AT A SINGLE SITE ("No, the old power plant used to be over there, I think, and you know they closed that road over there in 19 ought 76, or so, and I remember the time when we didn't have these motorbikes,..."!)
10. p. 119, a little past the middle; hang on: "A linear-regression analysis of the Hubbard Brook data <I'm glad that these chemists can at least use their pocket calculators> against time indicates..."
and then (last paragraph)

"The Hubbard Brook record ... appears in toto <a nice touch> to demonstrate a reduction in sulfate concentration <okay so far> SIMILAR TO THE GENERAL REDUCTION IN SO2 EMISSIONS...."

Hello. Why did you slip that one in? I mean, what about a inverse relationship with the cost of gasoline? How about inversely with the distance of the Pioneer spacecraft from earth? WHAT THE DEVIL ARE YOU GUYS DOING? IS THAT ALL IT TAKES TO SATIFY A CHEMIST THAT THERE IS A RELATIONSHIP BETWEEN TWO VARIABLES? YOU'VE GOT TO BE KIDDING!
11. p.123, 3L from bottom (just for fun): "Obviates the usefulness of these data." Cute. Meaningless, but cute.
12. p.126, bottom. You know, a statement like the following could really upset a person. "The most reliable data available in a continuous record are those from Hubbard Brook. These data comprise the direct historical evidence for an emissions-deposition relationship <from Farmer Brown's tractor to ...> and show no indication of a significant nonlinearity." But why get upset. After all, these chemists are right: these data show no indication of a significant nonlinearity. Of course, they don't give any indication that the system is linear, either. But they do show that the bird droppings ...

WHAT, PRAY TELL, IS YOUR TEST FOR "SIGNIFICANT NONLINEARITY?" IN FACT, WHAT IS YOUR TEST FOR ANYTHING. WHAT DO YOU DO? PUT A FEW CURVES ON THE SAME PAGE AND SEE IF THEY'RE GOING THE SAME WAY?!

It appears so, and therefore (to devestate your only other basis for suggesting that the system is linear) I would have you make one more plot:

12. pp. 127-131. Here's what I want you to plot. Take the molar ratios for Europe (given in Table 4.7) and plot them against distance, say from your Region 1, and then add the data for N. America (your Fig. 4.17, p.130). Sure, it'll be crude:

Station	Distance (deg. lat.)	Ratio (normalized)
Europe:		
1	0	1
2	4	1.2 or .7
3	5	1.2 or 1.3
4	8	1.8 or 1.3
5	14	2.0 or 3.8
N. America:		
PA	0	1
Adirondacks	2	1.2
Quebec City (Your 1.6)	5	1.6

OKAY, NOW PLOT THEM. NOW, WHAT WERE YOU GUYS SAYING ABOUT CONSTANT MOLAR RATIOS????????????
This is so bad that even if I weren't out of time, I don't know how I could continue. Pure unsubstantiated bull! The opposite conclusion to theirs is staring them in the face!

Quickly, to the end:
13. p.133, middle: point measurements are useless; you already told us that you can't identify local contributions.
14. p. 133 bottom, 135 top: the area-wide average removes the important spatial variation.
15. p.135, L.6: "No retardation of SO2 oxidation ..." B.S. Plot the above table.
16. p.135, next paragraph: "Net oxidation of SO2 is as efficient.." B.S. Look again at Pack's paper, and then why the difference in summer vs. winter?
17. p.136, top: "No evidence of strong nonlinearity..." B.S. How about the spatial trend (which you chose to ignore) and the seasonal pattern?
18. p.136: I think my opinion about your inference need not be detailed.
19. p.136, middle: "If dry deposition is linearly proportional to emissions (as suggested in the section on principal-component analysis), then ..." Sorry, fellas, that must have been in an earlier draft; it's not there.
20. p.136, middle: "Without greater confidence in deterministic models..."
And would you mind, terribly, defining what you mean by "confidence".
21. p.138, middle: "We lack .... to predict, either qualitatively or quantitatively..." Are all those words really necessary?
22. p.138, back to "empirical observations" and "seriously

nonlinear".

FINDINGS AND CONCLUSIONS

1. p.139,L1: Great: "empirical data". Hey, I just thought of at least one highly appropriate use of the word empirical: this is an empirical report! ("relying or based on ... without reference to scientific principles"!)

2. And so on it goes, repeating the gargage.

X. RESEARCH NEEDS

Well done, but please: "Direct empirical observations in the field", and how about suggesting the scientific approach. You know: the old business about hypothesis, test, hypothesis, test,... Surely you jest. You must have heard about it. Yah, it's a great way to cut down on the number of wild speculations. No, like .. Well, once I read this empirical report and it said.....

P.S. Someone slipped it in again:
p.149, buried, you can find: "A limitation of oxidant in winter is believed to be a princial cause of such nonlinearity." Shh. Don't tell the chairman.

CLOSING COMMENTS

I was asked to review this report. No one asked for my opinion abaout the issue. But I'd like to add it.

I don't disagree with the general implication of this report. If depositions are to be reduced, then it seems more reasonable to decrease emissions than to increase them.

My disagreement is with the details in this report. A group of scientists, representing us all, were asked to examine the issue and report their examination. They went astray into the linearity vs. nonlinearity issue, and there is no scientific basis for the conclusions they present.

My point is this. We don't know if the system is linear or not, but if emissions are reduced, depositions will likely follow ... eventually. Otherwise, what should we do?

Reviewer F

By and large, the Committee has made a useful contribution by bringing before the public--in rather the most effective fashion to date--findings of many years of research on the transport, transformation, and deposition of airborne pollutants. Nevertheless, we do have some differences of opinion relative to the Committee's conclusions, differences that are primarily matters of scale and degree. But at this stage of developing knowledge of these complex atmospheric processes, and at this point in the developing consensus for some as yet poorly defined legislative action, these differences could have far reaching consequences.

The NRC/NAS report makes a number of conclusions and recommendations which we believe are either not convincingly supported by the evidence presented, or for which we prefer alternative views supported by the evidence of our own work. These include statements such as:

1) On an annual time scale and over a 1000-km spatial scale, the formation and deposition of sulfate do not appear to be significantly nonlinear.
2) Current operational models of transport and deposition are inadequate for policy analysis.
3) Relative contributions of specific source regions to specific receptor sites are unknown.

Since each of these points deals in some way with the question of the relative "validity" of current models, it is difficult to discuss them separately. The following attempt to do so proceeds in the order presented above.

The NRC/NAS report limits its finding of "no significant nonlinearity" to the larger scales given in 1), above. Our reservations in this regard are concerned with the improved definition of these scales, specifically the determination of the shortest transport times and smallest distances below which neglecting nonlinearity could have important consequences. Time scales over which nonlinearities may affect policy should be accomodated in the design of emission control strategies. Clearly these scales are related to ecological and material effects; effects on lakes and watersheds do seem to be largely long-term--perhaps seasonal, as in snowmelt shock. But if shorter term ecological "insults" are found to be important in current research (for example, effects on vegetation at critical stages of growth), than the magnitude of time scales for nonlinearity would need reexamination.

The 1000 km spatial scale is much larger than the distances between many combinations of source and sensitive-receptor areas. The possibility of nonlinearity over shorter distances would therefore have to be considered for the consequences of potential emission control policies to be assessed accurately. Then too, even if a uniform rollback policy were adopted, all emission sources could not be uniformly reduced because of economic or equipment constraints. Instead, rollback amounts would probably be defined over some political entity of medium scale, such as a state. Current emission levels per BTU vary widely now, and some sources are much more amenable to emission control actions than others. For instance, if a plant has already installed a scrubber, little additional emission reduction could be required of that plant if it is to continue to operate. Thus, rollback could not be expected to be uniform even when totaled by state. In short, the NRC/NAS report appears to address the issue of deposition reduction by control legislation too narrowly.

We agree with the report's conclusion that nonlinearities are more likely to occur in winter, when many transformation and removal rates are slower and transport generally faster. But even this is a qualified agreement pointing up the issue of scale: specifically, over just what distances would nonlinearity be expected to limit the efficacy of rollback legislation in these--or any--weather conditions? The consequences of the interpretation of nonlinearity are too far-reaching to be based on the limited data used.

The evidence cited by the NRC/NAS report in support of their argument for linearity is a) the ~ 15-year record of weekly bulk deposition collected at Hubbard Brook, New Hampshire, b) historical SO_2/NO_x emission estimates , and c) the observed spatial patterns of molar ratios of SO_2/NO_x emissions and sulfate/nitrate wet deposition. An apparent trend of decreasing sulfate deposition at Hubbard Brook is associated with a trend of decreasing SO_2 emission in the Northeastern U.S. But there are several difficulties with this analysis:

1. No uncertainty ranges are placed on any of the emission totals. Since the SURE, MAP3S, and MOI inventories for a single year (1978) show differences in total emissions by states of 30 to 40 percent, the historical emission data used may be equally--or even more--uncertain. Such uncertainties would swamp the apparent effects of any actual emission change.

2. Trends in Canadian emissions are not considered at all; yet the Canadian contribution to bulk deposition received in central New Hampshire, i.e., at Hubbard Brook, is probably about 25 to 40 percent of the total.

3. The apparent decrease in sulfate deposition at Hubbard Brook largely results from reference to relatively high values recorded in the initial years (approx. 1965-1969). Since that time, there appears to have been little or no further decrease in sulfate deposition, even though emission inventories over subsequent years did continue to decrease. Meteorological variability could have accounted for this deposition record, even if there had been no change in emissions; or a single, not-too-distant source operating only in the earlier years may have gone unnoticed.

4. The decrease in the molar ratio of the sulfate/nitrate bulk deposition at Hubbard Brook also seems to result primarily from a high ratio recorded in the late 1960s followed by irregularly lower values in subsequent years. The Hubbard Brook data suggests a step function rather than a trend. The possibility of analytical error--or a change in analytical technique--could be considered.

5. The NRC/NAS report does not resolve the paradox of the apparent evidence for linearity in the Hubbard Brook data and the evidence for nonlinearity in the European data. The comparison between statewide SO_2/NO_x molar emission ratios and sulfate/nitrate wet deposition ratios used to support the linear hypothesis, is not conclusive. For example, some preliminary results of modeling sensitivity tests now underway at this Laboratory suggest that the sulfate/nitrate wet deposition molar ratio is relatively insensitive to the SO_2/NO_x emission ratio; thus a decrease in SO_x emissions may not be proportionally reflected in a subsequent decrease in sulfate wet deposition.

6. The discussion concerning whether or not the Rodhe model is adequate without a chain-carrying radical to continue the reaction, glosses over the limitation imposed by the fact that both versions of the set of equations used are essentially clear-air chemistry models, and are therefore not directly relevant to wet deposition processes.

With regard to present models, we would suggest that the relative utility of many recent assessments indicates that a number of the numerical simulations now in use have been demonstrated to be adequate for policy analysis. Future improvements in modeling now proposed (and evidently advocated for future use in assessment by the NRC/NAS report) are more likely to improve diagnostic details and field experiment design than contribute directly to improvements in policy assessment exercises. Yet the report recommends against the use of current transport and deposition models for policy assessment, thus recommending , in effect, that no cost/benefit assessment be done at this critical time of legislative decision. These negative views on present modeling capability seem to be based upon the level of parameterization necessary for tractable models, and upon the Committee's perception of the results of the now outdated MOI model intercomparison.

Taking the second point first, there were many uncertainties in the 1978 SO_x emission inventory for North America used by the MOI comparison. Further, the precipitation chemistry samples used for model verification were monthly collections and were almost entirely derived from southeastern Canada. Finally, most of the models compared had only two months of 1978 meteorological data available to them. It follows that the MOI model intercomparison was hardly a rigorous test, especially in view of the improved data sets (not to mention the improved models) available today. The NRC/NAS report does concede that some present models "quantitatively point to the importance of certain geographical groupings of SO_2 sources and the potential influence of (those) sources on certain receptor areas". It can be added that some of today's parameterised models consistently reproduce, in realistic fashion, average (monthly and longer) downstream deposition patterns attributable to large groups of sources, in the form of so-called source-receptor matrices. A numerical model developed and used at this Laboratory, for example, achieves this degree of success with objective parameterizations of mixing, transformation, and removal processes which are based on actual measurements made in ad hoc field experiments. In other words, the model has not been arbitrarily tuned to attain this performance.

This brings us to the third point of difference. On the basis of our modeling experience, we believe that average monthly and seasonal contributions of specific source regions of significant size (say, half the area of a medium sized state) to receptor regions of similar size up to 1000-1500 km downstream, can be simulated with present models sufficiently well to make objective assessments. But until the emissions from particular source regions can be identified in deposition samples, or until large scale field experiments can be performed with realistically reacting/depositing tracers, no transport/deposition model of source/receptor relationships can be rigorously verified. Present models use real fields of meteorological data, after the fact. Indeed, it is recognized that whenever possible, assessments over a certain period (month, season) should be based on models run with several years of data in order to limit the effects of meteorological anomalies. We do not believe that there is any realistic need for a truly dynamic transport and deposition model that would operate in a meteorologically predictive mode.

ORAL DEPOSITION OF RICHARD KLEIN

Presented before the U.S. Senate Committee on Environment and Public Works
Washington, D.C. 2 November 1983

My name is Richard Klein. I am Professor of Botany at the University of Vermont and co-director of the Acid Deposition Project. Our research is supported by the R.K. and A.W. Mellon Foundations, the Texaco Foundation and the Jackson Hole Foundation, plus federal funds. For the three years prior to September 1983, we received funding from the American Electric Power Service Corp.

Independently of sources, transport or transformation, present depositions in New England are acidic with average weighted pH values of 4.1 -- at least 10 times more acidic than non-anthropogenic precipitations. Some precipitation events are over 50 times more acidic. Acidic rain and snow contains significant amounts of metals including cadmium, copper, lead and zinc which have accumulated in the soils. Highly acidic snowmelt is 10 times as acidic as the bulk snow. Snowmelt and precipitation solubilizes indigenous aluminum and deposited heavy metals that enter the soil water solution and can adversely affect plant development. At elevations above 2200 feet, cloud water, which is five times more acidic than rain and contains higher concentrations of metal, condenses on foliage, hence, the acid and metal load at higher elevations is much greater than at lower elevations.

Our field research started in 1965 and we now possess the best field data base in North America for high elevation forests. Complete floristic and climatic studies in 1965, 1979, and 1983, have been statistically compared. Briefly, our major study area, Camels Hump Mountain, plus other Vermont mountains are disaster areas. In both hardwood ecosystems and in the northern coniferous forest the dominant tree species -- sugar maple, beech, mountain and striped maple, red spruce, white birch and balsam fir, have shown steady declines in vigor and survival. Only 30% of the red spruce present in 1965 are alive today and similar, but less dramatic declines have been measured for the other tree species. This is also true for many seedlings and saplings. The litter -- leaves and needles that have fallen from the trees -- has doubled in depth since 1965 with corresponding reduction in decomposition and the cycling of scarce nutrients. Mosses that carpet the forest floor and prevent erosion have decreased in coverage by 50%. The regeneration of red spruce by germination and establishment of seedlings is almost nil. Once dead, trees are windthrown and the forest is an almost impenetratable tangle. These, too, are facts substantiated by appropriate techniques and the sequence of ecosystem failure is also seen in other parts of North America and Europe.

The obvious question is whether there is a cause and effect relationship among the meteorological facts of acidic deposition, the facts on alteration in the composition and quality of the nutritive soil solution and facts on the destruction of hardwood and northern coniferous forests in the mountains of New England and elsewhere. Our studies have shown that impacted ecosystems show a particular set of characteristics. They are, in the northeast, primarily westerly-facing slopes of mountains with soils that are shallow to bedrock, naturally acidic, low in nutrients and with high levels of organic matter. These are harsh environments with periods of drought, excess water, wide variations in temperature, and high winds. Trees are continually under environmental stress. It is, a situation where the additional stress of acidic deposition becomes too much to bear.

Concommitant with our field studies, we are conducting laboratory simulation experiments in which we isolate a single ecosystem component and evaluate the possibility that this stress -- acid, metals, etc. -- can be a contributing factor to the observed decline of the forest. Although time does not permit me to provide you with a resume of all of our studies, a few highlights will demonstrate our approach and our findings.

1. Acid loads and metal concentrations that mimic natural conditions repress the activities of soil microorganisms that cause the decomposition of litter and the release of nutrients needed for forest plants.

2. Increased litter depths prevent tree seedlings from establishing in soil.

3. Acidic depositions can leach nutrients from this litter and move these chemicals away from the ecosystem.

4. Acids and metals depress the growth of moss and can account for the depauperization of the moss coverage on the forest floor.

5. Acids and metals can significantly reduce the ability of red spruce and balsam fir trees to take up and move water and nutrients through the tree.

6. Acids and metals in hydroponic cultures can kill spruce with the sequence of death mimicking with some precision the sequence we have observed in the field.

7. Acids and metals can reduce the growth of the root systems of seedling red spruce and can cause the death of the seedlings.

8. Acidic artificial cloud water can leach nutrients, carbohydrates and even proteins from needles of spruce and leaves of birch.

9. Acids and metals can reduce the growth and vigor of those soil fungi that form mycorrhizal associations with forest tree roots. Many studies have shown that reduced water and mineral uptake of non-mycorrhizal root systems limits the growth and development of forest trees.

10. Metals, solubilized from indigenous and deposited metals by acidic depositions and highly acidic snowmelt water are accumulating in the annual rings of sugar maple and red spruce. Solubilized indigenous aluminum and deposited vanadium concentrations in wood have been greatly increased since the 1940-1950 period, the decade when it is believed that widely dispersed acidic deposition began.

We are determining whether there has been a significant decline in the growth rate of hardwood and coniferous trees from Camels Hump Mountain. These studies are not complete, but should provide a reasonable estimate of the existance or non-existance of a decline in growth which is of considerable economic and environmental importance.

We are continually evaluating the possibility that the observed and measured alterations in mountainous ecosystems may be due to causes other than acidic deposition. Disease and insect damage are very unlikely to be directly involved. The evidence has tended to rule out possible drought as a major causal factor, although drought is certainly a stress that, combined with other stresses, is a factor in ecosystem destabilization.

We and other discount drought as a primary cause of ecosystem failure on several eco-physiological grounds.

a. There have been many droughts of some duration over the past 150 years as seen in our tree ring studies and, in every instance except for the present, the trees survived and rebounded.

b. The syndrome of tree decline and death is seen now in young trees that were not established in the 1960 period.

c, Drought resistant as well as drought sensitive tree species are now dying.

d. The upper elevation forests on Camels Hump, receiving large amounts of cloud water condensate, were not dry during this period. Weather station reports of precipitation at low elevation sites do not reflect the pattern of dry periods in mountains. Quantitative soil moisture measurements made during this period support our contention that the coniferous zone forests were not experiencing a drought.

e. The sequence of morbidity and mortality characteristic of drought stricken trees is visibly different from that which we are seeing.

If the weatherperson on the evening news tells you that there is a 10% chance of rain, it is unlikely that you will carry an umbrella, but if you hear that there is a 90% chance -- more properly, a 90%

probability -- of rain, you will wear a raincoat and carry an umbrella. In acid deposition studies, we too deal in probabilities, since absolute proof in the legal or even the scientific sense is unlikely ever to be obtained. Based on our studies, and those of meteorologists, soil scientists, terrestrial plant ecologists, and physiologists throughout the world, there is a high probability that acidic depositions are the primary and proximate cause of the destabilization and destruction of terrestrial forested ecosystems of mountainous areas in New England and elsewhere. We and others have not been able to provide an alternate explanation that is consistant with all the available facts.

We are aware that no one has unequivocal proof for the contention of an acid-metal causation of forest damage. Additional research certainly will narrow the gaps in our knowledge, but will never be fully adequate simply because of the complexity of terrestrial ecosystems and the absence of a control area in North America that is not receiving acidic depositions. We believe, however, that the evidence is sufficiently compelling and the probability of cause and effect is sufficiently high to warrant legislation designed to reduce significantly the production of acidic and metal-containing pollutions. Based on our research and that of others, as well as on solid ecological and physiological grounds, we believe that significant reductions in acidity and metal content of both wet and dry depositions will lessen the stresses now literally destroying forested, mountainous ecosystems. Even if such reductions were to be immediately implemented, it is likely that some damage to forests may be irreversible.

CAMELS HUMP - ABOVE GROUND BIOMASS ESTIMATES BY FOREST ZONE (All Tree Species > 2cm)

Year of Measurement	1965	1979	1983	% change '65-'83
HARDWOOD (1800-2400 ft)	269,871	238,684	218,208	- 19%
TRANSITIONAL (2600-2800 ft)	135,175	145,335	119,983	- 12%
BOREAL (3000-3800 ft)	142,520	113,877	84,217	- 41%

ABOVE GROUND BIOMASS BY TREE SPECIES (>2cm)

	Kilograms per hectare ($\bar{x}$) 1965	1979	1983	% change '65-'83
Sugar Maple (Acer saccharum Marsh)	135,584	114,860	102,937	- 25%
Beech (Fagus grandifolia Ehrh.)	66,695	46,621	49,997	- 25%
Yellow Birch (Betula lutea Michx.)	39,876	51,137	45,851	+ 15% (-10 since '79
Red Spruce (Picea rubens Sarg.)	30,381	17,373	8,698	- 71%
Balsam Fir (Abies balsamea L.Mill.)	51,763	48,521	41,948	- 19%
White Birch (Betula cordifolia Regel.)	30,253	34,915	19,817	- 34%
Mountain Maple (Acer spicatum Lam.)	1,672	714	647	- 61%
Striped Maple (Acer pensylvanicum L.)	978	744	753	- 23%
Mountain Ash (Sorbus americana)	1,755	1,514	1,071	- 39%

Testimony on Acid Rain: Acidification of Lakes and Streams and Impacts on Aquatic Organisms

by

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Acid rain and deposition of acidifying gases and particles affects large areas of eastern North America and Europe. In regions in which the soils possess limited natural capacity to counteract the acid inputs, streamwaters, lakewaters and groundwaters are acidified. The water becomes acidic and acquires toxic forms of metals such as aluminum. Fish populations are lost, and other organisms at every level of life are affected.

Acid deposition falls as wet precipitation such as rain, snow and fog and dry deposits such as fine particles and gases. The acids come from the emission of coal and oil and the smelting of metal ores. These gases react in the atmosphere to give sulfuric and nitric acid and can be transported hundreds of miles before being deposited.

Large areas of eastern North America and Europe receive acid deposition 10-30 times greater than natural levels (Likens, et al. 1979). The increase in deposition is due to increases in pollutant emissions which in turn are due to increases in burning of coal and oil.

When acid rain falls in areas in which the soils are rich in lime, no harmful affects to the lakes and streams occur. But when acid rain falls in sensitive areas, areas in which soil cover is often thin and by nature poor in base substances, the lakes and streams are acidified to unnaturally high levels. Such sensitive areas are located in many regions of the United States and Canada (Galloway and Cowling, 1978). The Adirondack Mountains of New York, parts of New England, much of the

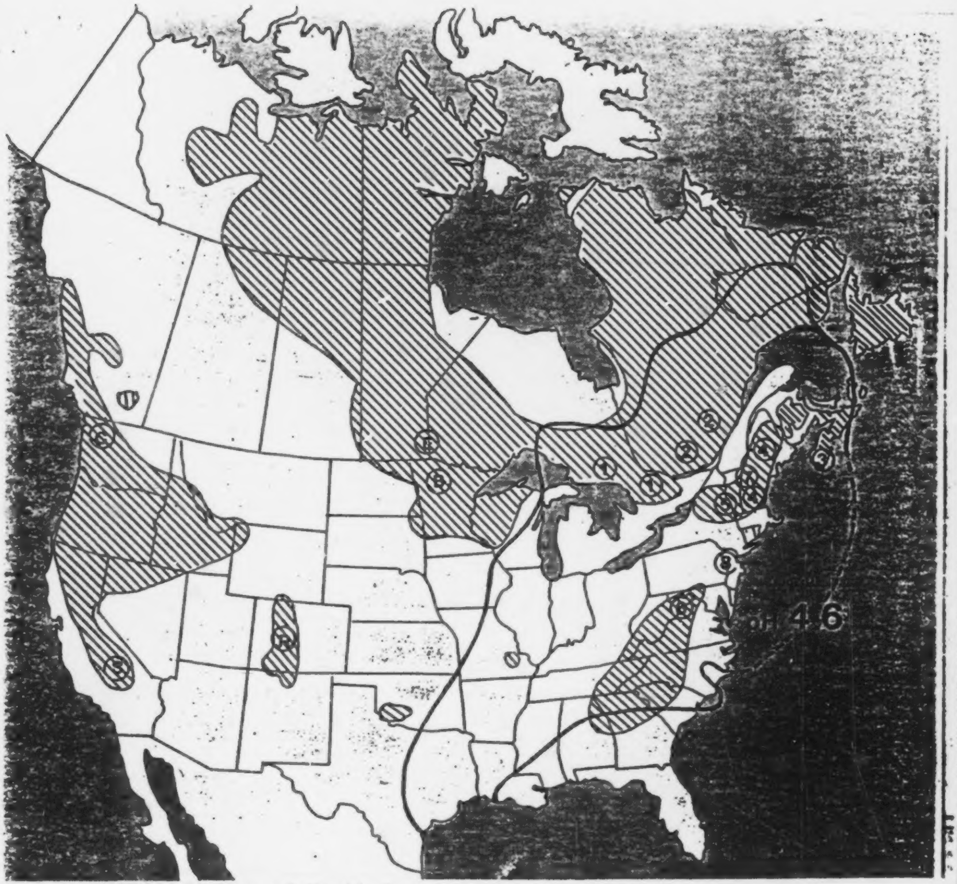

Figure 1. Map of North America showing the locations of areas sensitive to damage by acid precipitation (hatched). The region within the pH 4.6 isoline receives precipitation with weighted-average pH less than 4.6, the threshold at which the most sensitive freshwaters are acidified. Acidified lakes and streams have been reported from numerous areas within this region (numbers). Freshwaters in sensitive areas not receiving acid precipitation are not acidified (letters). (Source: J. N. Galloway, pers. comm.)

Appalachians, parts of the lake-rich regions of the Upper Midwest, the Rocky Mountain National Park in Colorado, the Sierra Nevada of California and the Pacific Cascade Mountains are all naturally sensitive areas. In Canada vast regions of Ontario, Quebec and the Maritime Provinces are sensitive (Figure 1).

The harmful environmental impact requires the combination of acid rain and sensitive areas. In regions not sensitive acid rain causes no harmful effects to the aquatic environment. Lake Erie will never be threatened by acid rain. Conversely, waters in sensitive areas not receiving acid rain are not acidified. The lakes of the Sierra Nevada exhibit normal water chemistry and support healthy fish populations. The threshold for adverse effects in the most sensitive lakes is when rain has a pH level lower than about 4.6-4.7. This corresponds to a sulfur deposition of about 3-4 times natural levels (Wright and Henriksen, 1979).

The combination of acid rain and sensitive areas produces an unusual type of lake and stream. These waters become dilute solutions of sulfuric acid. The greater the acid deposition the greater is the concentration of sulfate in the lakes and streams (Figure 2) (Wright, 1983). And the greater is the likelihood that the area will be sensitive enough to become acidified. Toxic forms of aluminum are present. And the aquatic life is altered dramatically. Fish populations are lost due to recruitment failure and mortality of adult fish (Figure 3). Other animal and plant species decline in abundance or disappear

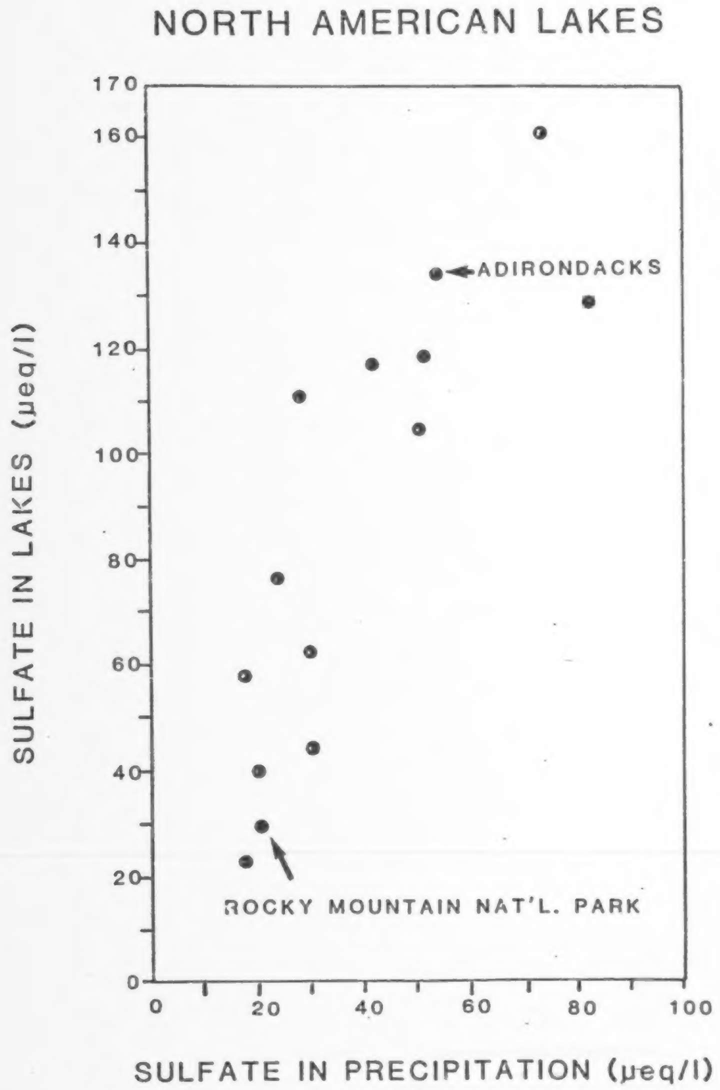

Figure 2. Sulfate levels in precipitation and in lakes and streams surveyed in 15 areas of North America. (Source: Wright, 1983).

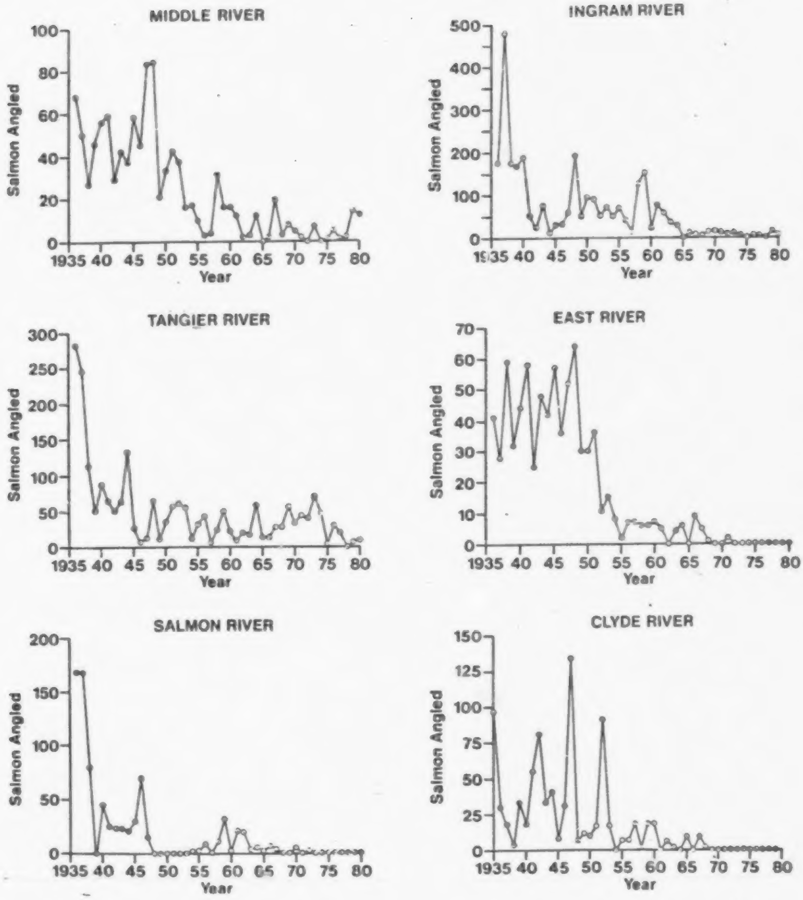

Figure 3. Salmon catch histories for 6 rivers in Nova Scotia that are acidic today (mean annual pH in 1980 below 5.0). (Source: Watt et al. 1983).

(Hendrey et al.,1983). The effects can be seen at every level in the food chain (Figure 4). In many cases the loss of trout or salmon represents only the tip of the iceberg of ecological change.

In the Adirondack Mountains of 40 lakes surveyed, 21 have no fish present in 1975 but all but 4 had fish present in the 1930's (Schofield, 1976). In 6 rivers of Nova Scotia the salmon catch has declined sharply since the 1940's (Figure 3) (Watt, et al. 1983). The historical evidence stored in the sediments at the bottom of the lake itself also points to a major change in acidity during the past several decades (Figure 5) (Charles, in press).

The magnitude of the environmental effects of acid rain grows as additional sensitive areas are systematically surveyed. The problem grows as the results of additional research come in. For example recently the acidification of groundwater and drinking water supplies has been reported.

The evidence overwhelmingly points to major large-scale environmental change over large regions of North America and Europe during the past several decades. Thousands of lakes and streams are known to be acidified and have greatly altered plant and animal communities. Acid rain is the only known viable explanation for the changes. Only acid rain fits in space and time the regional pattern of lake and stream acidification. The fit is so good that acidification in areas not yet investigated can be predicted.

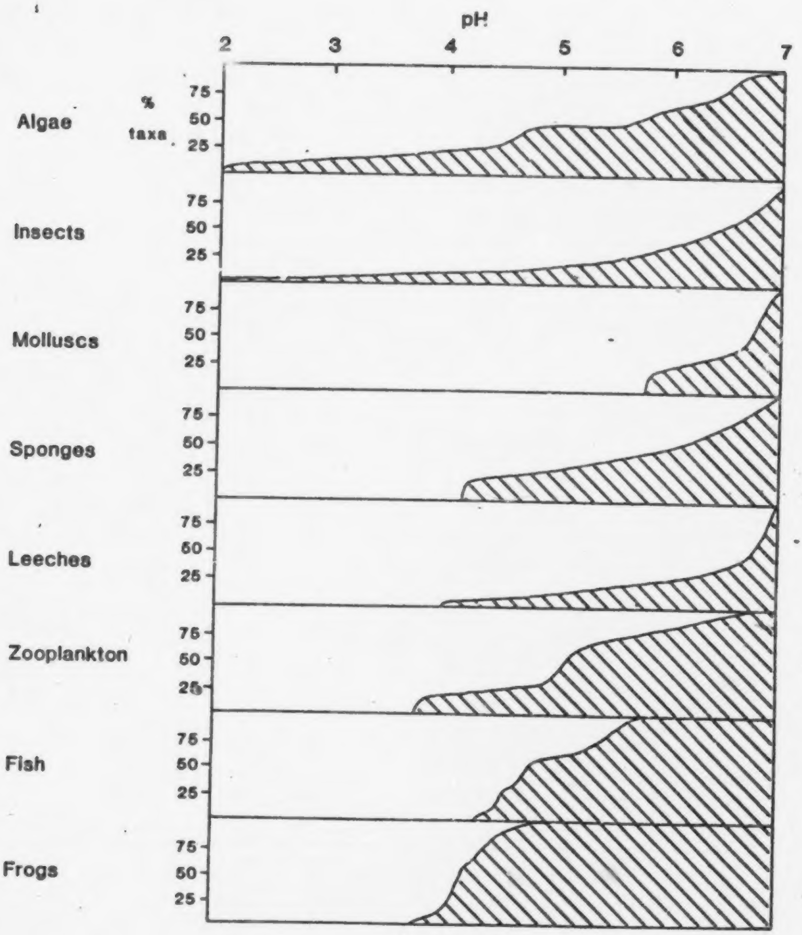

Figure 4. All major groups of aquatic organisms are sensitive to increasing acidity. As pH declines the number of species found at each level of the food chain declines. (Source: Eilers and Berg, 1983).

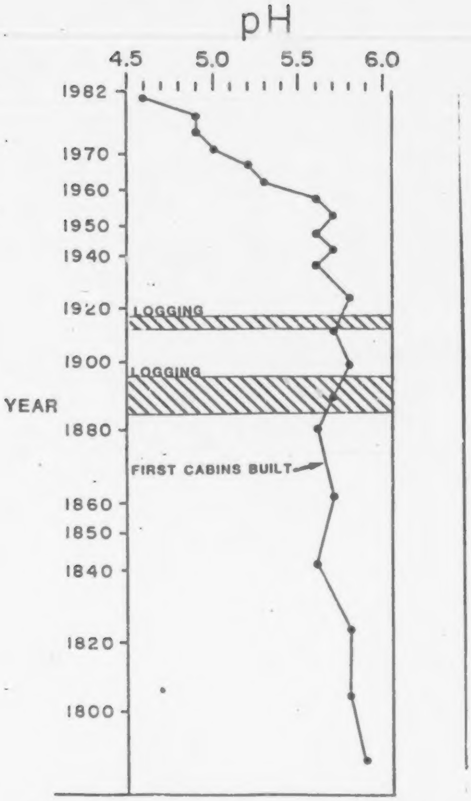

Figure 5. pH history for Big Moose Lake, Adirondack Mountains, NY, reconstructed from diatom remains in the lake sediments. Historical records indicate logging in the catchment to Big Moose Lake in the late 1800's and early 1900's and cabin development beginning about 1870. Acidification of the lake apparently began after 1950 and continues to the present. There were 14 species of fish in the 1930's; in 1983 only 9 species were present, 4 of which are non-native species introduced since the 1940's. (Source: Charles, in press).

Critics have rejected acid rain as the cause of this environmental change (Rosenquist, 1978; Krug and Frink, 1983; Richter, 1983). They argue that acid deposited from the atmosphere is minor compared to that produced and stored in the soils typical of sensitive areas. They claim that the widespread acidification of lakes and streams is due to changes in land-use such as forest cutting which have changed the soils.

These objections can be met in two ways. First, although it is true that soils in sensitive areas contain large amounts of acid, these acids are not naturally transported out of the soil. A vehicle is required. The sulfate, and to a lesser extent the nitrate, contained in acid rain provides the vehicle to transport the acid out of the soil (Johnson and Cole, 1980). Thus acid rain is a necessary factor (Figure 6).

Secondly, the geographical distribution of acidified lakes and streams cannot be explained by land-use change (Overrein et al., 1980). Many of the affected areas are pristine and have never been subject to land-use let alone land-use change. Whereas land-use change such as logging occurred at different times at different lakes, the acidification and loss of fish populations have occurred all within the past several decades. The logging at Big Moose Lake in the Adirondacks apparently caused very little change in the lake's acidity (Figure 5) (Charles, in press). The major acidification has occurred since 1950. Finally, major land-use change in sensitive areas not receiving acid rain has not resulted in acidification or loss of

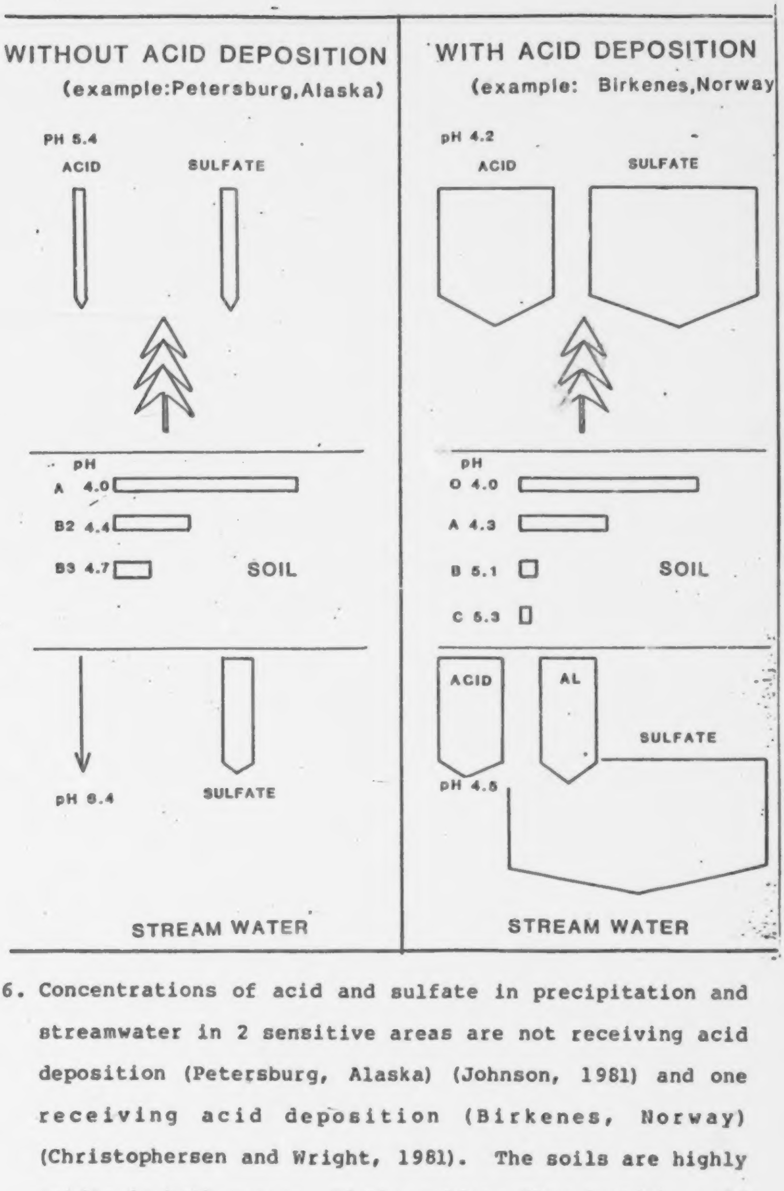
WITHOUT ACID DEPOSITION
(example:Petersburg,Alaska)
PH 5.4
ACID
SULFATE
pH
A 4.0
B2 4.4
B3 4.7
SOIL
pH 6.4
SULFATE
STREAM WATER
WITH ACID DEPOSITION
(example: Birkenes,Norway
pH 4.2
ACID
SULFATE
pH
O 4.0
A 4.3
B 5.1
C 5.3
SOIL
ACID
AL
SULFATE
pH 4.5
STREAM WATER

Figure 6. Concentrations of acid and sulfate in precipitation and streamwater in 2 sensitive areas are not receiving acid deposition (Petersburg, Alaska) (Johnson, 1981) and one receiving acid deposition (Birkenes, Norway) (Christophersen and Wright, 1981). The soils are highly acidic in both areas. If the sulfate flux is high, acid can be transported out of the soil and the streamwater will be acidified.

fish populations. In the sensitive areas of northern Minnesota, major watershed disturbances such as clearcutting and forest fire cause ecological changes on both the land and in the lakes but these changes do not include acidification (Wright, 1976). The land-use hypothesis cannot explain the observed regional pattern of lake and stream acidification and therefore must be rejected.

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November 4, 1983

Senator Robert Stafford, Chairman
Committee on Environment and
  Public Works
U.S. Senate
Washington, D.C.

My dear Senator Stafford:

I am writing as an economist who has conducted extensive studies of the economics of environmental policy over the past 15 years. I would like to have the following statement entered in the record of the hearings on acid deposition control which are being held this month.

The debate concerning the appropriate policy toward acid deposition has focused primarily on whether any reduction in sulfur emissions is necessary, and if so, how large should it be. With the recent reports of the National Academy of Sciences and the Office of Science and Technology Policy Panel, it appears increasingly likely that Congress will enact some sulfur control measure.

As an economist I have no special competence to discuss the scientific issues of photochemical conversion, atmospheric transport, or the effect of acid deposition on ecological systems. And I do not believe that the state of the art of economic analysis and measurement will permit the selection of a target level of emissions reductions on benefit-cost grounds. I do believe however, that whatever size of emissions reductions is finally settled upon, it is of vital importance to design a policy to achieve that level at the lowest possible cost to society. This point has tended to be lost in the debate over the proper size of the reduction, if any. Many of the current legislative proposals contain provisions which would significantly increase the total cost of emissions reductions over the least-cost alternative. These proposals are deficient in one or both of the following respects: they mandate excessively costly techniques of sulfur removal; and they do not achieve the least-cost allocation of responsibility for emissions reductions among sources.

I believe that no acid deposition control legislation should mandate the installation of a specific type of control technology, that is, scrubbers. Nor should legislation create artificial incentives to sources to choose scrubbers through subsidies and cost sharing for capital costs. Rather, each source should be free to choose the lowest-cost method for meeting emissions reductions standards given its particular circumstances. Several of the bills presently before Congress would mandate the adoption of scrubbers for large utility sources and/or provide artificial economic incentives to choose scrubbers through subsidies to capital costs. If utilities were free to choose the least-cost method for achieving emissions standards, many would choose low sulfur coal instead. It has been estimated that a scrubber requirement would increase the total cost of achieving significant sulfur emission reductions (in the range of 8-12 million tons per year) by as much as 30-35%. For example, one bill to require reduction of 10 million tons per year includes a requirement that the 50 largest utilities install scrubbers. This bill is estimated to require annual costs of $4.2 billion. Allowing utilities to choose the least cost method of achieving standards would reduce the total cost by $1.0 billion to $3.2 billion per year. Although the forced scrubbing approach may provide some job protection to miners of high sulfur coal, this protection could be provided more economically and effectively via direct means.

I believe that an economically sound acid deposition policy should avoid a rigid allocation of required emissions reductions among sources without regard to differences in the costs of control among plants. Rather a policy should be adopted which results in relatively greater levels of control by sources with low control costs while allowing high cost sources to continue relatively high levels of emissions, provided that the target level of emissions reduction is attained in the aggregate. Means of accomplishing the least cost allocation of responsibility for emissions reductions among sources while meeting an aggregate emissions reductions target include marketable or tradable emissions permits, emissions offsets, and allowing interfirm "bubbles" for sources in the same region.

Whatever the outcome of the political debate over the desired level of emissions reductions, I urge Congress and the Environmental Protection Agency to work together to devise an economically sound, cost-effective strategy for achieving that target. Those advocating a significant reduction in acid deposition have argued that this is necessary for the health of the environment. But it is equally important to the health of the economy that these reductions be achieved in a cost effective manner.

Sincerely yours,

A. Myrick Freeman III
Professor of Economics

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